ESSAYS

ON THE

NATURAL HISTORY AND ORIGIN

OF

PEAT MOSS:

THE PECULIAR
QUALITIES OF THAT SUBSTANCE;
THE MEANS OF IMPROVING IT AS A SOIL;
THE METHODS OF CONVERTING IT INTO A MANURE; AND THE OTHER ECONOMICAL PURPOSES TO WHICH IT MAY BE MADE SUBSERVIENT.

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1810.

TO

HIS GRACE THE DUKE OF ATHOLL,

THE PRESIDENT,

AND THE OTHER MEMBERS OF THE

HIGHLAND SOCIETY OF SCOTLAND,

THESE ESSAYS ARE DEDICATED

BY THE

AUTHOR,

AS A SMALL

TRIBUTE OF HIS ESTEEM AND GRATITUDE,

AND A

HUMBLE TESTIMONY THAT THEY WERE THE FIRST

IN BRITAIN,

TO CALL THE ATTENTION OF THE PUBLIC

TO THE NATURAL HISTORY AND ORIGIN OF PEAT MOSS, AND

THE IMPORTANT ECONOMICAL PURPOSES

TO WHICH IT MAY BE MADE SUBSERVIENT.

MANSE, KILSYTH,
April 23*d* 1810.

ADVERTISEMENT.

The Author feels himself under the strongest obligations to those Noblemen and Gentlemen who have honoured the work with their patronage; and he finds it necessary to apologise to *them* for his delaying the publication of the Practical Essays. Though already prepared for the press, he declines to publish them now, for the following reasons: He fears, that, as his account of the natural history of that substance is novel, it may be incorrect. As the Practical Essays are founded on the principles stated in those now published, and as a variety of experiments are now making on an *extensive scale*, in different parts of the Empire, on the plans he has suggested, he deems it more respectful to the Public, to withhold the subsequent part of the work, till their opinion of these Essays, and the result of these experiments, be ascertained; lest he may inadvertently lead

any of his countrymen to attempt improvements on erroneous principles.

In every part of these Practical Essays, he has endeavoured to carry experience along with him, as the safest and surest illustration of these principles. With this view, he has collected, and is still in the way of procuring, information from most parts of Europe, on the practice pursued by different nations in cultivating moss as a soil, converting it into manure, or fuel, or other economical purposes. These Essays will therefore be entirely practical, and expressed in language as free as possible from technical terms, and such as every cultivator may easily understand.

The short Outlines of the Practical Essays are subjoined at the end of this volume; and the whole will be published with as much expedition, and sold at as low a rate as possible.

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In these Essays some technical terms have unavoidably been used. As they may be unintelligible to some readers, the following Vocabulary may be consulted.

VOCABULARY.

1. *Oxygen* is one of the ingredients of the atmosphere, and a constituent principle of the acids, and many natural compounds. It has been called *vital* air, as it is absolutely requisite for the life of animals.

2. *Azote* is another ingredient of atmoshperic air. That air consists of nearly seven parts of azote to two of oxygen. The former is as fatal to life, when alone, (hence its name) as the latter is favourable. But when both are combined in the proportion above named, they constitute the air we breath.

3. *Hydrogen*, as its name imports, is the basis of water. It is specifically much lighter than atmospheric air, and highly inflammable. Hence it was called inflammable air by the ancients. When it combines with oxygen, it forms water; hence its name.

4. *Carbon* is the name given to the pure inflammable base of charcoal. It is seldom found pure. Generally it is combined with a little hydrogen and oxygen, and other foreign ingredients, derived from the substances from which charcoal is prepared.

5. *Carbonic acid*, is a compound of carbon with oxygen. When pure, it exists in the form of gas. It was called fixed air by the old chemists, and is fatal to life when breathed.

6. *Phosphorus* is a substance highly inflammable. It exists in, and forms a constituent part of animal matter, and of several vegetables.

7. *Gallic acid* is found chiefly in those vegetables which have an astringent property; and it was once regarded as the principle of astringency. This quality, however, seems to arise more particularly from another vegetable principle, called *tanin*, as it operates chiefly in tanning leather. These two, the gallic acid and tanin, are often found to accompany each other.

8. *Pyrites* is a combination of metals with sulphur. With iron, sulphur forms iron pyrites. With copper, it forms copper pyrites. When exposed to moisture and air, they take fire. Hence the name *pyrites*, or, as it has been called, *fire-stone*.

9. *Sulphats* is the name applied to all the salts formed by the sulphuric acid. When iron is the base, it is called sulphat of iron. So, when copper, or potass, or ammonia form the base, it is called sulphat of copper, of potass, or of ammonia.

10. Carbonates, muriats, &c. are salts formed of the same bases, with carbonic, or muriatic acid.

11. *Surturbrandt*, is a species of coal, which contains, and seems chiefly to be composed of ligneous plants, or trees, nearly in their original organic form.

12. *Bovey coal* is similar to surturbrandt.

ERRATA.

P. 256. l. 3. for *former* read *latter*
408. l. 9. for *h*ennel read *k*ennel
437. l. 20. for *co*verted read *con*verted
485. *Note*, *foot*, for H*ie*mbla read H*u*mbla
462. The Sections of the VI. Essay are wrong numbered, for *V.* read *VI.* &c. &c.
626. l. 3. for the*n* read the*ir*

ESSAYS

ON THE

NATURAL HISTORY AND ORIGIN

OF

PEAT MOSS.

INTRODUCTION.

NATURAL History is become the favourite study of all the nations of Europe. Great exertions have been made to elucidate every branch of this delightful subject. The vegetable, mineral, and animal kingdoms, have been surveyed with the most critical minuteness, and much light is daily poured in on every department of these.

The only branch that seems to have been overlooked is that of Peat Moss. Though it exists, nay abounds in every region of the north of Europe, and though it is every day under the eye of the philosopher, the natural history and origin of this substance has been neglected for ages.

By some it seems to be regarded as a mystery beyond the reach of science itself; by others it is looked upon as beneath their notice. While the chemist and natural historian, in a course of lectures, minutely describes every other substance, no attempt is made to elucidate the origin, or account for the distinguishing qualities of peat moss; and in no one language is there to be found a complete treatise on the subject. There are many loose hints thrown out occasionally, and a variety of chemical experiments have been made by men of science; but no author has hitherto collected these scattered fragments, or attempted to form a clear or satisfactory hypothesis on the subject, from a collection of well-attested facts.

Nothing can be a more convincing evidence of the universal neglect, and imperfect knowledge of this branch of natural history, than the many incoherent and inconsistent theories that have been espoused and defended, by men of distinguished talents of different nations.

In general they agree in supposing, that ligneous plants have chiefly contributed, in one shape or another, to the formation of that substance; but as to the manner in which that process has been effected they differ widely. Some suppose that moss is altogether formed by alluvion. They are of opinion, that it consists of the leaves and twigs of trees, washed down from the declivities and mountains into the vallies by rivers and floods; and that these, in a

course of ages, have been converted into moss by the mixture of reeds and aquatic plants. Others have supposed that it is a certain species of native soil, on which ligneous and aquatic plants naturally grow; and that these, by their continual decay, originally formed, and still continue to form moss.

Picard, Lemnius, Piganiol, and Grammaye are of opinion, that it is a congeries of bark, boughs, leaves, and roots of trees, or of whole forests, overset and immersed in water, mixed with grass and reeds.

Lentilius and Commelinus think that it is a marshy bituminous earth, mixed with ligneous and aquatic plants, putrified under water. They suppose that Holland, at one period, was an extended forest, and that this was overflown by an inundation of the ocean: That, of course, the wood thus overset sunk in the mud, and by the accession of particles of earth, deposited by the waters, formed the immense mosses of that country.

Stevinus thinks that it is a fat sulphuro-bituminous earth of rotten wood. He supposes that the leaves, &c. of trees which grew on rising grounds, after being reduced to earth, have been washed down into the vallies, and thus, in a course of ages, have been converted into moss. He adds, as a proof of this, that black rich mould, if frequently washed with water, yields a solution which, when filtered and evaporated, leaves a residuum of a sulphureous and inflammable nature like peat, and not distinguishable from it.

All these respectable authors agree in this general opinion, that moss is of vegetable origin, and that ligneous plants have chiefly contributed to the formation of it. As to the manner in which that process has been carried on, and the various changes and combinations that have been accomplished by it, they seem to have formed no clear or decided opinion.

Other authors, equally respectable, have supposed, that all moss is of mineral origin. Scheuchtzer was of opinion, that it is a mere fossile bituminous earth, only accidentally mixed with vegetable matter. Stahl was of a similar opinion. In his Fund. Chem. he says, that it is a bituminous mineral subterraneous substance. Morhoffius, in his Polyhist. calls it a mineral earth, and classes it with coal. He says, that it differs from mold, as it is more inflammable, and swims on water, whereas mold sinks.

Some have even supposed that moss is a primitive earth. Guiccardin and Oudhoff, &c. adopt this opinion. They imagined that it is a distinct species of earth peculiar to marshy levels: That, by the singular providence of God, this earth has been provided for the use of man: That, though partly carried off, the germ still remains; and, by the annual increment of aquatic plants and alluvial soil, it is renovated.

Others have supposed, that all mosses were originally lakes; that, when these were drained or filled up, they were converted into moss. The bitumen and sulphur they contained were supposed, by O'Dap-

per, to be the cause of this change, and of communicating inflammability to that substance. He therefore describes peat in the following words: "It consists of bitumen, asphalt, and naphtha, mixed with "leaves, &c. of trees and aquatic plants." He quotes Agricola de Ortu Subterran. in corroboration of this opinion, who says, that no fat earth is inflammable unless it contain bitumen and sulphur.

Some of the Dutch have supposed that moss is a marine production; that, being torn up from the bottom, and tossed about by the waves of the ocean, it is thrown ashore. The spongy reedy turf called *dary*, is, of course, they say, often found in the bottom of the sea near Antwerp, and elsewhere; they therefore conclude, that it has been originally formed there. It contains a liquid bitumen, and a portion of sea salt.

Others have supposed, that peat moss is a growing vegetable, *sui generis*. This opinion has been adopted by some of the Dutch writers upwards of a century ago; and Dr Anderson, in his Essay, strenuously defends it.

It is almost unnecessary for me to add, that some writers of distinction, and almost all the vulgar, are of opinion, that moss is of antediluvean origin. Dr Morton supposed that the strata of peat found in Northampton and other parts of England, with all the trees they contain, were deposited by the deluge. Every peasant is of opinion that this has been univer-

sally the case with all peat mosses, and that none are of more recent origin.

Such a variety of opinions, so discordant, clearly proves, that this subject has been either much neglected, or, at least, that the origin and natural history of peat moss has not been hitherto elucidated in a scientific and satisfactory manner.

This neglect is unaccountable, if not criminal. Whether we consider the vast extent of surface covered with moss in every kingdom of the north of Europe, or the various and important purposes it is calculated to serve, the subject must rise in importance in the estimation of every enlightened mind; and it must appear astonishing, that a subject so interesting and so important has hitherto been so much neglected.

It is utterly impossible for me accurately to ascertain the number of square miles covered with moss. It may, however, arrest the attention of the reader to give a rough guess at it.

I shall name a few mosses. These are by no means the most extensive; they are not selected as such; yet they may suffice to give a faint view of the vast extent of surface covered with that substance. At one period, perhaps, the whole of that surface was rich arable land, or, at another, an extended forest.

Hatfield moss, in England, seems to be of this description: It contains upwards of 180,000 acres. Some of the mosses in Ireland are still more extensive. Dr Boates speaks of one on the Shannon, fifty

miles long, by two or three broad. Carr, in his Stranger in Ireland, says, that the bog of Allan alone contains 300,000 acres. Blavier mentions some mosses in France, probably of much greater extent. The great marsh of Moutoire, near the mouth of the Loire, he says, is more than fifty leagues in circumference. And Mons. De Luc says, that the moss of Bremerford, near Bremen, is upwards of sixty miles long, by twelve or fifteen broad: At a moderate calculation, it must contain upwards of 600,000 acres. In other places of Holland, Germany, Poland, Prussia, Sweden, and Russia, I might point out some of double or treble that extent. To calculate the number of acres these may contain, would be an unavailing task; for though that calculation were correct, it could only give a very imperfect view of the vast extent of surface covered with moss in the north of Europe. Innumerable millions of acres lie as a useless waste, nay, a nuisance to these nations. The benefits that might accrue to Europe by a slight attention to this subject are above all calculation. It is impossible for numbers to express, or the imagination to conceive, correctly, the extent of these.

I speak not of moss as a soil only; there are other economical purposes it is calculated to serve, of equal importance; yet the cultivation of it as a soil alone is important. The following statement, in the communications to the Board of Agriculture, will shew this in a satisfactory manner: It is said that, in Cambridgeshire alone, there are not less than 150,000

acres of waste unimproved fen. By a moderate improvement, these might be made to yield 10s. per acre, so that no less than 75,000l. of yearly rent might thus be added to that single county. According to Dr Halley, Cambridgeshire is only a seventieth part of England and Wales. If the above results be multiplied by 70, the number of acres that lie waste, may be 22,351,000 in these kingdoms alone. At a moderate rent of 10s. per acre, they might yield upwards of 10,000,000l. At 30 years purchase, these would add 300,000,000l. Sterling to the national capital.

The above is surely no more than an ideal calculation, and perhaps it ought not to be allowed to be correct. For, although Cambridgeshire be only a seventieth part of England and Wales, it is not probable that all that kingdom contains the same proportion of unimproved moor and fen, with that single county; yet the calculation is valuable; and the subject cannot be too often or too strongly pressed upon the attention of the public.

Beatson in the First Vol. of the Communications to the Board of Agriculture, calculates, in general, that there are upwards of 20 millions of unimproved mosses and moors in Britain. He supposes that there are upwards of seven in England, and 14 in Scotland.

The proportion of improveable fens and marshes and mosses, in Ireland, it is likely, is far greater than in either.

Is it not, then, astonishing, and is it not to be lamented, that a subject of such national importance has hitherto been so shamefully neglected? Is it not a reproach to every nation in Europe? Ought it not to be deprecated by all ranks? And ought not every potentate of these vast dominions to blush at the recollection? Shall they spend the treasures and the blood of their subjects in the wild schemes of ambition, in seeking to extend their dominions, and aggrandize their nation and their name by new conquests, while kingdoms lie uncultivated in their own empires, and myriads of acres of their richest vallies lie as a useless waste? If but one ten thousand part of the treasures wasted in one campaign, were devoted to the improvement of these uncultivated regions, then might the wilderness be made to smile, and the desart to bud forth and blossom as the rose; then might the voice of melody and health be heard in the peaceful cot of the lowly peasant, in place of the sound of the trumpet, and the alarm of war.

The heath covered mountain would no longer shew its unseemly front, but be cloathed in all the verdure of spring. In place of impassable fens, the waving corn and yellow harvest would adorn the vallies. The peasant would no longer need to pine for want of food or employment, or pant for distant climes. While the upstart tyrant and his creatures, in France, pant for honour, and pursue the path that leads to it, all drenched in blood, let Britons of all ranks direct their attention to the toils of a healthful, happy pea-

santry; let them diffuse the light of science over the British Isles, and point out and pursue the mighty plans of economical improvement, especially of the neglected fens and mosses.

Say that the task is arduous: say not that the difficulties are insurmountable, or that it is a forlorn hope to make the attempt. These difficulties are not once to be named with those with which the industrious Dutch have long contended, and at last surmounted. While they have converted seas into dry land, and impassable fens and lakes into fertile plains, let none despair of seeing the mosses of Europe converted into purposes equally important and useful.

It were a fruitless attempt in an obscure individual to endeavour to rouse the attention of the potentates of Europe to this subject: yet when I see such spirited attempts in Britain, and so many rapid improvements already made, and every day making, in every department of agriculture; and, more especially, when so many of the first rank and first talents in the kingdom, have formed patriotic societies for the encouragement of that most noble of all arts, I cannot but flatter myself, that even my feeble efforts may arrest the attention of some of my countrymen. And I hope the time is not far distant, when the Natural History of Peat Moss, like every other branch of that delightful subject, shall be elucidated.

It is the pride and distinguishing glory of Britons, that they excel all the world in the art of agriculture. Mons. Mirabeau, in France, was forced to acknow-

ledge this. "The English," says he, "have been "the first to establish the principles of agriculture in "Europe, and to discover that this is the foundation "of all other arts, and the very hinge on which all "commerce ought to turn." Don Jos. Volcarel was obliged to bear a similar testimony: "It must be "acknowledged," says he, "that England has open- "ed the eyes of other nations. These islanders have "discovered at last, after many schemes, that it is "agriculture alone which forms the source and ori- "gin of their greatness. If, on these principles, we "were to calculate the progress of that monarchy, "we would find their power to have increased in a "threefold degree, and that this has been augmented "in proportion to their improvement in this art." When I see such a testimony from the most enligh- tened enemies of my native country in her behalf, I feel an honest elation of heart; and when I think that the maritime power and flourishing commerce of Great Britain depend so much on her internal re- sources, and especially on the improvement of her soil, I am not without hopes that peat moss (the only part that has been neglected) shall soon arrest the at- tention of every patriot, and call forth the talents of the distinguished chemist.

To rouse the attention of all ranks to this subject, and especially that of the patriotic societies in Scot- land, England, and Ireland, and, if possible, that of the Senate itself, is my great object. With this view I have, at my leisure hours, prepared a number of

essays on the natural history and origin of peat moss. These are ready for the press, and will be published in succession. I have likewise prepared a number of essays on moss, as a soil, a manure, a fuel, &c. &c.

The first five essays are entirely devoted to the natural history and origin of that substance. Till this be clearly ascertained, every attempt to improve it as a soil, or convert it into manure, must be hazardous. Experiments may be made, but, in that case, they are only made at random: And, perhaps, nine-tenths of these attempts have originated in ignorance, and therefore failed. Even of those which have succeeded, the greater part of that success may be ascribed to accident; and accidental discoveries, without knowing on what principles they proceed, cannot be deemed satisfactory.

To point out the origin and distinguishing qualities of peat moss; to ascertain, if possible, the chemical principles on which it may be converted into a soil or manure, or turned to other economical purposes; and, above all, to show that no disappointments ought to damp the ardour of Britons, or make them despair of success, is the great end I have in view in these essays.

In the prosecution of this subject I have felt the most pleasing amusement. It has been a fund of delightful recreation to me for years. Prompted by a sense of the importance of the subject, and still more encouraged by the polite attention of the Highland

Society and the Board of Agriculture, I have pursued the plan with perseverance.

My obligations to them are great and many. I feel, too, and am proud to express, the high sense of gratitude I owe to the Curators of the Advocates' Library, for the liberal manner in which they furnished me with the books they had, and even procured some from the Continent on the subject.

It might hurt the delicacy of individuals were I to express, in this public manner, my obligations to them. It is enough to say, I feel, and ever will retain, a grateful sense of these.

To the University of Glasgow, and every Member of that learned Society, I am under such obligations as I cannot, and therefore will not attempt to express.

ESSAY I.

ON LIGNEOUS PLANTS.

AN

ESSAY

ON THOSE

LIGNEOUS PLANTS

WHICH LAY THE FOUNDATION,

AND FURNISH MATERIALS FOR THE FORMATION,

OF

MOSS.

THE natural history of Peat Moss is very obscure; and, it is probable, that it will never be fully elucidated. Many ingenious and plausible theories have been suggested upon the subject. Without enumerating all of these, I shall endeavour to state and support those which appear to me the most rational and consistent.

It is almost universally allowed to be of vegetable origin; and it seems to be the general opinion, that it is either a congeries of ligneous or aquatic plants, or of both. To these two sources all the mosses of the North of Europe may be traced.

In this Essay I shall confine myself to *Ligneous Plants:* and endeavour to trace up many of our mosses to this source.

SECTION I.

It is the opinion of eminent men, that the whole habitable earth was originally covered with woods; and that it continued to be so until mankind formed themselves into societies, and subdued these by fire or steel. Dr Darwin, in his Botanic Garden, gives this as his decided opinion, in so many words. St Pierre thinks that the whole earth, if left uncultivated, would become a forest. He thinks, that even the Alps and Pyrenees were once covered with wood.

It cannot be denied, that there are facts which tend to corroborate this opinion. I shall state a few of these, which are well known, and need no attestation.

1. When the earth is uninhabited, and allowed to lie in an uncultivated state, trees of all kinds spontaneously spring up and flourish, each in the soil and climate suited to its species.

2. Even land at present in cultivation, if enclosed, and allowed to lie waste, in the vicinity of a forest,

will speedily be covered with wood. The seeds of various trees are scattered over the surface; there they strike root, and spring up in abundance.

3. Most of the glens and precipices, especially in low sheltered situations, inaccessible to cattle, are covered with copse-wood.

4. Many regions of the earth, both in the old and new worlds (as they are called), when first explored, were one extended forest: And the remotest regions, which the traveller has never trod, in all probability, are similar to these.

Whether this opinion be well founded or not, it is certain that the north of Europe once abounded in woods and forests, more than now. It appears that trees have flourished even in the cold inhospitable climate of Lapland, where scarcely a tree or shrub is now to be seen.—They are dug out under the perpetual snows of that region.

It is impossible to trace the changes in the climate, and the consequent changes in the productions of different regions of the globe, up to a very remote period. History leads us back only a few hundred years. But we have both geographers and historians of credibility who bear testimony, that, eighteen hundred years ago, the north of Europe abounded in forests, in many places where scarcely a tree can now be seen.

Ptolemy is one of the most ancient of our geographers: and, considering the period at which he wrote, he is very correct. Let any person look at his map

of Europe, he will see, that, in the south of that quarter of the globe, there were few forests of any considerable extent. In Spain, Portugal, Italy, and Greece, there appears to have been none.

In the north of Europe forests appear to have been numerous and very extensive in his days. In Germany they are so immense as to make a very conspicuous figure in the map. Helvetiorum Sylva, Gabrieta Sylva, Hircinia Sylva, Somana Sylva, cover immense tracks, and give the whole of Germany, &c. the appearance of one extended forest, with only a few interstices of open land.

Ortelius corroborates the testimony of Ptolemy. According to his representation, Arduenna Sylva (now Ardennes) seems to have covered one third part of ancient Belgium. The Hircinian forest seems to cover more than one half of Germany:

Whereas, according to these geographers, there was not a single forest, of any considerable extent, in Asia, Africa, or the south of Europe. The Pyrenees are, indeed, represented as partly covered with wood at that period; but in no place is there the appearance of any forest so far south, excepting upon these mountains *.

The testimony of historians, upon this point, is equally decided and clear. Cæsar, Tacitus, Pliny,

* It is not asserted that no forests did ever exist in the south of Europe. The probability is that they did abound as much, if not more, than in the north.

All that I mean to insinuate is, that this was not the case at the period alluded to.

Pomponius, Strabo, and Tyrius, all agree, that the forests of the north of Europe were numerous and extensive.

I shall not give a detailed account of these forests. A few quotations respecting the extent and situation of the most remarkable may suffice.

Cæsar was the conqueror of Gaul; of course, he narrowly inspected that country, and points out its topography with minuteness: He gives a distinct account of the *sylva Arduenna* in his days: He calls it a forest of vast extent, and by far the greatest of all Gaul. He points out its limits: He says it reached from the Rhine, through the territories of the Treviri, to the conflux of the Schelde, and the Maese; so that it extended upwards of 500 miles.

Strabo gives a similar account of its extent. His words are "*efficiunt hæc quatuor millia stadiorum.*"

Pomponius describes Gaul as abounding in forests. He calls it "*Terra amœna lucis immanibus.*"

The Hircinian forest is described with equal precision. Pliny says, that it covered almost the whole extent of Germany. Cæsar and Pomponius both agree that it was no less than nine days journey in breadth, and 60 in length. It seems even to have been more extensive; for it is added by the same authors, that no man, in those days, had ever reached the extremity of it.

If we were to trust to etymology, the prevailing names of these districts would indicate that most of Germany, and a great part of the United Provinces,

was once covered with wood. The very name Holland indicates this. Degner observes that *Holt* signifies wood. Holland, therefore, must signify the woody country; and all those districts, whose names terminate in *holt* or *hout*, *would*, *woed*, *wolde*, &c. indicate that they were originally forests. Seven *wolden* is still the name of the seven forests of Friezland.

It cannot be doubted that the forests of the north of Europe were more numerous and more extensive 2000 years ago, than they are at present. It seems probable that they do not occupy one-fifth, perhaps one-tenth, of the space they did at that period.

This point I have been at some pains to establish. It would, however, tend to the elucidation of this subject, if we could ascertain the causes of this change.

SECTION II.

1. In proportion to the progress of agriculture forests decrease. Every new settler in North America clears a part of that country of wood, and converts it into a cultivated soil. A similar change,

doubtless, ensued in the North of Europe; and the more rapid the progress of agriculture, forests would disappear in proportion.

At the remote period of the Roman invasion, the inhabitants of the greatest part of the north of Europe seem to have been ignorant of the arts of cultivation. Like the wandering tribes of North America, they seem to have depended for their subsistence, in a great measure, on the spontaneous productions of the earth. They lived by the chace: or, if they had herds and flocks, these were but few in number, in proportion to what are now reared in that region.

This may be one cause why forests abounded at that period. Few were cut, with a view to cultivate the soil. The young plants, or seedlings, of every species, were suffered to spring up with less injury from man or beast. Besides this, the different arts, introduced into the north of Europe, occasioned a great consumpt of fuel. The forests that abounded would naturally present themselves as the readiest means of supplying that article. The quantity thus consumed, in France alone, from the want of coal, and other combustibles, must have been great; and economical writers have often raised the alarm that, by this means alone, the whole woods of France will soon be consumed.

2. Besides this, the rude nations of the north, at that early period, had a religious veneration for their

forests. They were all druids; they worshipped under every green tree; forests were deemed sacred to their deities; each had its peculiar divinity; and some trees were regarded as peculiarly sacred.

Maximus Tyrius mentions, that the OAK was worshipped by druids of every nation; that, for this cause, it was carefully preserved. He also adds, that the fir-tree was the favourite of the Danes, and preserved by them with equal care.

These two species were the most abundant of all the trees of the forest. To injure or destroy them would be deemed a deed of sacrilege; to preserve them would be esteemed an act of religious homage. But,

3. There were civil as well as religious motives, which prompted them to preserve these forests. These rude nations, at that remote period, made frequent inroads upon one another Each was ready to fall a prey to his neighbour. When overpowered by numbers, or unable to meet the invading foe in open field they fled to their woods for succour and for safety. These offered a secure retreat; thither the enemy, though numerous, durst not pursue them.

The Roman historians bear testimony to this. They all agree that the inhabitants of Britain, and the north of Europe, retreated to their woods on every emergency. There they rallied; from thence they rushed forth, with impetuous fury, upon the foe. Cæsar mentions many instances of this. Cassibelaunus, after his defeat, retired beyond the Thames,

and took refuge in the woods and marshes: The Silures, when attacked by Agricola, did the same: Venutius, king of the Brigantines, imitated their example.

The same historian observes, that these nations had few cities or fortified places; that their woods, surrounded with a rampart and ditch, served them for a bulwark and strong-hold. As such they would be preserved with care.

The great object of the invader would be, on the contrary, to destroy them, and thereby cut off the natives from a secure retreat.

This leads me to point out,

SECTION III.

The Means by which these Forests were destroyed.

1. It will naturally occur to every one that *some of these have decayed through age.* This is the universal law of nature. Every herb, fruit, and flower fadeth. The lofty cedar, and the stately oak,

that have stood for ages, at last tumble into ruins; and the fashion of the world passeth away.

This account of the matter may appear satisfactory to some, perhaps plausible to all; but it is only plausible; and it will, by no means, account for the great and general wreck of these forests.

It is with the vegetable as with the animal kingdom; one generation goeth, and another cometh, in endless succession.

Every tree yields fruit after its kind; these naturally drop each species upon the soil suited to its production (that is, near the parent tree.) There they would spring up; and thus one generation would naturally supply the place of another. Du Hamel, accordingly observes, that the seeds of the fir tree, which drop in the forests of Bourdeaux, in August, open by the heat of the sun, and spring up so thick that it is necessary to thin them from time to time.

In place of a forest's decaying through age, it is probable that, in some situations, it may be renovated; and, it is certain, that the new generation must exceed the old, both in number of trees and extent of surface.

That this has been the case with some of our ancient forests, which now lie in ruins, appears probable, from the following circumstances:—

1. (*a*) The trees found in our mosses are, for the most part, perfectly straight. Even oaks, which are most apt to spread in a crooked branchy form, where

they have room to extend, are often found 90 feet long, without a bend, or the appearance of a bough.

2. (*b*) The roots of trees are often found so thickly studded in the subsoil of moss, that it is hard to conceive how they could extend to such a size in so small a place.

These circumstances render it probable, if not certain, that such forests have been originally very thick set.

There are other circumstances, that render it equally probable that one generation has risen upon the ruins of another.

1. (*a*) In many mosses one tier of roots appear perpendicularly above another; yet both are fixed in the subsoil.

2. (*b*) In some even three tier appear, in succession, the one above the other.

3. (*c*) In other cases, the branches of the trees that have been overset continue to grow, while the trunk decays. These branches send out new roots, which take a new hold of the soil, and thus form a new generation. In the Phil. Trans. No. 275, this appears to be the case in Hatfield moss, and elsewhere.

4. (*d*) It is a well known fact, in natural history, that the roots of many trees may be converted into branches, and the branches into roots. If the tree be overset, and the roots turned up, so as to have access to air and light, they vegetate like branches, and grow into trees: If, on the contrary, the branches be covered with earth, and thus cut off from access

to air and light, they are converted into roots, and serve the same purpose. Cordiner, in his antiquities of the North, mentions an instance of this in Mar Forest. A large pine, with spreading branches, arrested his attention. One of these branches, by the weight of timber, had reached the ground; there it had taken root; for many years it had grown; a new tree had sprung up from this new stock: By the impetuosity of the storm this new tree had been torn up; and the roots and branch, and tree that had sprung from it, hung high suspended in the air.

5. (*e*) Even, in some cases, trees are found still growing upon the ruins of others, after they have been converted into moss. De Luc mentions that, in Kidinger Moor, trees are still growing, though there is three feet of moss formed on the surface by the ruins of former generations. Dr Walker mentions a similar instance in the moss of Strathcluony.

All these circumstances combined, render it probable, that time alone will not account for the general wreck of our forests; at least, it appears certain, that they may survive for several succeeding generations, before they finally decay through age.

Other causes may be assigned, and no doubt have co-operated in this great catastrophe: nor can it be ascribed to one cause. We are not to suppose that every forest has undergone the same fate.

There are, however, evident marks,

2. *That some have yielded to the storm, and been overset by hurricanes.*

In every age, and in every quarter of the globe, the stateliest trees and the most extensive forests have been overset, or totally ruined, by the impetuosity of the tempest. Cæsar, Tacitus, and Pomponius, all agree that Gaul, in their days, was exposed to tremendous hurricanes. They speak of whole forsets being overset by tempests of wind. Tacitus, who knew both countries, describes Germany as being still more exposed to such tempests than even Gaul. He speaks of the largest oaks being thereby overset; and, he says, that their extended roots and branches and trunks, when thus overblown, gave them the appearance as if whole mountains were moved.

Thus trees which stood on the firmest foundation, and had the fastest hold of the earth, may yield to the storm; much more those which sprung up in a looser soil; and, most of all, those which had risen upon the ruins of former generations:—their roots would naturally sink into the mass of leaves and boughs and trunks in search of nourishment; of course, having a less firm hold, they would more readily yield. When the rains descended, and the floods came, and the winds blew, they would be more easily overset.

Besides this, if it happened that several feet of moss had been formed, during the growth of these trees, they would, on this account, more easily yield to the storm. Senebier shews, by experiments, that

a tree sunk in the earth, half its length, will speedily perish; the same must take place if it be sunk in moss. Chilled by this means, it must be checked in its growth, and readily yield to the impetuosity of the tempest.

Mons. De Luc, in a letter to me in January last, makes a similar remark :

" That there have been vast forests in the north of
" Europe, which no more exist, is ascertained by his-
" torical monuments; and it appears to me, that
" peat mosses have been one of the causes of their
" destruction: The accumulation of peat having
" softened the soil, the winds must have blown down
" the trees. Hence whole masses of the mossy sub-
" soil has, by this means, been torn up; especially on
" the banks of rivers and lakes. These have caused
" those floating islands which still subsist in the coun-
" try of Bremen, that I have described in my works.

" Trees thus overset must have sunk into the
" mossy subsoil, and added to the mass of moss. In
" this subsoil, the seeds they had dropped would
" cease to vegetate. The attempt to plant new trees
" on the spot has been vain; they are soon covered
" with a grey moss, which speedily destroys them."

Dr Walker mentions a recent instance of this. In the year 1756, the wood of Drumlanrig was overset by the wind; and many forests, both in Britain and on the Continent, have, no doubt, suffered the same fate. Hence, in many mosses, the trees are all broken over within two or three feet of the surface;

their trunks all lie in the same direction, a proof that they have yielded to the same element.

In the British Islands, they mostly lie in the direction from S. W. to N. E. because our prevailing winds and heaviest rains come from that quarter. I have examined many mosses in this neighbourhood, and found this to be the case. The same is said of Hatfield, Phil. Trans. No. 275, and Dr Collet says the same of Berkshire moss.

Junius, in his Histor. Batav. mentions, that in many mosses in Holland, though not in all, immense trees are found; that their roots all incline to the N. W. and their tops to the S. E. He says, that this is a proof that forests once abounded in those regions, and that they were overset by north winds, or incursions of the northern ocean.

It is of little consequence in what direction the trunks are found lying. If, in any moss, they lie chiefly in one direction, the probability is, that they have been overset by the wind.

No doubt other causes have combined to overset these forests. The hands of men have been employed for this purpose, and there are evident proofs that some

3. *Have been cut down.*

A number of well attested facts lead to this conclusion: Historians, both ancient and modern, bear us out in forming it. As this is an important point,

and tends greatly to illustrate the origin of many of our mosses, I shall endeavour to establish it, upon the most unequivocal evidence.

(*a.*) There are evident marks of the hatchet in many of our ruined forests, and in the deepest mosses, both in the British Islands and on the Continent.

Numberless instances of this must have occurred to the reader; I shall only point out a few that have been carefully recorded.

The Rev. Mr Tait, in his account of Kincardine moss, mentions, that it has been originally a forest; that it bears evident marks of having been cut; that the stumps of the trees are generally about two or three feet high. At that height, he adds, the diameter of a tree is generally less, and therefore more easily cut: the cutter can better apply his strength than at a greater or less height. Hence, in Russia, where wood abounds, and is used for fuel, they cut it about the same height. Mr Tait adds, that there are clear marks of the hatchet still to be seen; that it seems to have been two and a half inches broad; that there is no reason to suppose that this forest was overset by the winds, for none of the trees appear to have been torn up by the roots.

Mr Ure, in his History of East Kilbride, mentions a similar case. "A few years ago, the trunk of a "tree, with part of the root, was dug out of a peat "moss near Renfrew. In the trunk, a little above "the root, was found sticking an iron hatchet, of a "very uncommon kind."

Mr Aiton, in his essay on peat earth, says, that he has seen many thousands of trees in mosses that had been evidently cut.

In the Phil. Trans. No. 275, similar instances are mentioned in Hatfield moss. Some of the trees found deep in the moss are chopped, some squared, some bored through, others half riven with great wooden wedges and stones; and broken axe heads, similar to the sacrificing axes of the Romans, are found in them.

Dr Leigh, in his Natural History of Lincolnshire, mentions, that the trees dug out of the fens of that county bear evident marks of being cut; that the marks of the hatchet are still fresh and obvious. He adds, that, in some of the deepest drains, trees were found cut, squared, and formed into rails, stoups, bars, &c. &c.

In Somersetshire, Cheshire, Lancashire, Westmoreland, Yorkshire, Staffordshire, and *other* counties, the same author observes, that there are similar marks *of the hatchet* to be seen. He adds, that in the Netherlands, France, Switzerland, &c. there are the same.

Mr De Luc, who narrowly examined the mosses on the Continent, mentions, that there are evident marks of the hatchet to be seen on the trees dug out of Kedinger moor. Pontus Henterus says the same of all the trees dug out of the mosses of Picardy in France.

SECTION IV.

Of the period at which these forests have been overset, and by whom.

It cannot be expected that we can ascertain at what precise period, or by whom these forests have been cut; there are only a few scraps of history to direct our researches.—I shall name a few:

(*b.*) It appears from the history of Britain, that some of our forests, which are now mosses, were cut at different periods.

Even the records of the British Parliament bear evidences of this. At one period, the extensive forests became a national nuisance; they harboured wolves and wild beasts of prey: these were destructive to the live-stock, and sometimes dangerous to the inhabitants.—By several acts of the Legislature these forests were ordered to be destroyed.

Edward the First ordered the trees of Wales to be cut and burnt. Pembrokeshire moss, of course, may have been formed upon their ruins. And it is certain, that the trees dug out of that moss bear the marks both of fire and steel.

When Henry the Second conquered Ireland, he did the same in that country. The object of that prince was to prevent the natives from having any harbour in their woods, and harassing his troops.

Dr Boates, in his Natural History of Ireland, observes, that trunks of trees are found near Castle-

Forbes, which have been burnt, and that the ashes are still seen lying on the stumps of these trees. He ascribes the destruction of them, first to the Danes, and afterwards to the English.

In the wars of the borders, John Duke of Lancaster, to avenge himself of the depredations the inhabitants had committed, set 24,000 axes to work at once to destroy the woods. Perhaps Lammermuir, and the mosses of the borders may owe their origin to this or a similar cause.

King Robert the Bruce, when he pursued the Earl of Buchan to Inverary, destroyed some of the forests in that neighbourhod. In the Statistical Account it is said, that the trees then cut down are still found under the deep mosses of that district.

Other intances might be mentioned; but we must look to a more remote period of history for a more complete illustration of this subject.

(*c.*) The records of the Roman history furnish us with more ample and satisfactory evidence.

To that restless and ambitious nation we must chiefly look as the cause of the ruin of the forests of the north of Europe. The object of the Roman emperors was not only to conquer the barbarous nations of the north, but to SECURE their conquest. They were not satisfied, therefore, with having extended their arms from the Caspian to the Baltic Sea, and from the Pillars of Hercules to the Hebrides, they sought to establish their extended empire, and

to secure it from the incursions of the nations they had subdued.

During the short intervals of peace which they enjoyed, we accordingly find that they employed the legions of Rome, and oftentimes the inhabitants of the tributary provinces, in cutting down the forests and draining the marshes. Tacitus states this in explicit terms. Dion Cassius and Herodian join their testimony to the same effect. Severus, in his last expedition to Britain, is not only said to have given general orders for the destruction of all the forests of these provinces he had subdued, but to have lost 50,000 of his soldiers in that undertaking in Britain alone.

Throughout the whole of Britain accordingly, and a great part of the north of Europe, there are still to be seen evident traces of the Roman power in the ruined forests, mosses, and moors.

Roman coins, or utensils, or the remains of Roman works, have been discovered deep in these mosses.

I. Many Roman coins have been discovered in Scotland. I mention a few instances; others will occur to the reader. They ought to be recorded.

In Possil moss, near Glasgow, a leathern bag, containing above 200 silver coins of Rome, were found.

In Dundaff moor, a number were discovered about forty years ago.

In Annan moss, near the Roman Causeway, an ornament of pure gold was discovered.

Many have also been found in the English mosses.

In Lincolnshire fens, two or three coins of Vespasian, with the head of that Emperor on one side, and the Roman eagle on the reverse, were discovered.

In Hatfield moss a variety of these coins were found near the root of a tree deep in the moss.

A thousand coins of the Emperor Victorinus were discovered in the marsh of Mazarion in Cornwal;

And some have been discovered in the mosses of the Continent.

In Low Modena Roman coins were dug out of the marsh 30, 40, and 50 feet deep.

De Luc mentions that similar discoveries have been made all over the Continent. Mr Heerkens, in his Elegia de Terra Groninguensi, speaks of a coin of the Emperor Gordian being found 30 feet deep in moss, and many other phenomena, which shews these mosses to be of recent origin.

Besides coins,

II. Many utensils, of Roman workmanship, have likewise been found in these mosses.

A Roman camp-kettle was found eight feet under a moss in the estate of Ochtertire.

In moss Flanders a similar implement was found. A Roman jug was found in Locher moss, Dumfries-shire. A pot and decanter, of Roman copper, was found in Kirkmichael parish, in the same county.

Two pair of vessels, of Roman bronze, were discovered in the moss in Glenderhill in Strathaven; and in the Isle of Sky a chest of Roman arms was found under moss.

Degner mentions similar instances on the Continent. He says that all kinds of coins, antique stones, with various inscriptions, fragments of arms, earthen pots, &c. are dug out of these mosses.

But it may be said these utensils and coins were only dropt through accident, and sunk in these mosses after they were formed; or that they may have been buried there on purpose, so that they are no proof that these mosses were formed over them since the period in which they were deposited. It may be proper to add, that,

III. The remains of Roman works have been also found deep in these mosses. Many of these must have been executed before these mosses had a being. In the Dullatur bog some Roman altars were discovered when the great canal was dug; these are lodged in the University of Glasgow, and may still be seen. In a moss in the immediate neighbourhood of this, a beautiful Roman altar, dedicated to the nymphs, was found: It is still standing at Nethercroy, in the parish of Cumbernauld, near the spot from whence it was dug. In Ardennis a beautiful marble altar was found, dedicated to Diana.

It may be said, however, that even these were buried or sunk in the mosses where they lay, long

after these mosses were formed. There are other remains of Roman works to which this remark can scarcely be applied.

The Rev. Mr Headrick, in his Essay, Vol. II. Com. Bd. Agr. mentions, that the Roman causeway was lately discovered in the moss of Mr Fulton of Hartfield, near Paisley; that it lies on a bed of moss; but that over it several feet of moss has been formed.

Girard in his Hist. of the Valley of the Somme, in the north of France, mentions, that a similar causeway was discovered near the village of Brevilly, under the moss. That it is clearly the work of mens' hands; probably of the Romans. As an evidence of this, he adds, that this is the common tradition of the country; that many of the old forts in the neighbourhood have Roman names, or allusions to that nation; that one is called the camp of Cæsar.

Abbe de Bæuf. clearly proves, that the forts near Pecquingy are Roman; and he thinks this causeway, and the banks that intersect the moss, are the remains of Roman works. Hence they are still called *viez* from *via*. And one is called *viez du camp*.

Lambardie, who made a general survey, and gives a minute description of the mosses of France, states it as his decided opinion, that, in Cæsar's time, the banks of the Somme, though now an extended morass, were covered with woods and lakes: That the inhabitants were therefore called by the Romans *Morini;* by the Celts, *Mourinin*, or the inhabitants

of the moors and marshes: that, having these woods and marshes as a secure and safe retreat, they were therefore the last of all the Gauls that Cæsar could subdue.

Lest any doubt should remain on this subject, I may refer the reader to the Rev. Mr Tait's account of Kincardine moss. There a discovery was made of the Roman causeway, which leaves no doubt that that moss was an extended forest at the time of the Roman invasion; and that it was cut down by them.

The Roman causeway can still be traced through a great part of Britain. In the neighbourhood of Kincardine moss these traces are clearly seen. It enters upon the south of the moss at Craigforth; on the north of the same moss, near the river Teith, it is still visible: while it communicates with the moss on both sides, it seemed to be interrupted there. Traces of it have, however, lately been discovered, in digging that moss. After the peat, eight feet deep, was removed, the remains of this road were laid open to view. It is twelve feet broad; it is not paved with stones like the rest of that work; it is constructed of trees from nine to 12 inches diameter. Those forming the first tier are laid in the direction of the road; over these, another tier of trees, of half the diameter, are laid across. The whole is covered with brushwood. The first tier of trees generally lies on the surface of the subsoil of clay. In the lowest and wettest places they are sunk, as might be expected, two feet below the surface of this clay.

The same author adds; It can scarcely be doubted, this is a Roman work connected with the Roman road, and forming a part of it. And he concludes,

That before the time of Agricola, this level was occupied by a forest: That about that period this forest was cut down by the Romans: That from these trees thus cut down, and suffered to decay on the marshy grounds, originated the vast body of peat moss which now covers that level: That the age of the moss, therefore, cannot much exceed 1700 years.

De Luc, from a general survey of the mosses of the Continent, draws a similar conclusion. He says, that all along the mosses and moors, which he examined, there are Roman antiquities to be found; that there are evident marks that many of these mosses were forests, at the period of the Roman invasion; and, that it is more than probable, that these forests were ruined by that power.

Demoustier, in his account of the fossil wood, discovered near Paris, observes, That it appears from Cæsar's account of Labienus's expedition against the Gauls under Camelogenus, that all the neighbourhood of that city was, at that period, woods and marshes: That the inundations of the Seine overflowed these: That Camelogenus retreated thither: determined to wait the attack of the Roman legions: That Labienus attempted to force a passage through the morass, by twigs and branches covered with sod: That he found this impracticable: That he therefore went up as far as Melun, and, mounting 50 boats

with soldiers, sailed down the stream into the city: That the Gauls set fire to the city, cut down the bridges, and placed themselves beyond the marshes: That they were there surrounded, and completely defeated by the Romans. Gobelinus mentions, that moss is found at the port of Paris, where these woods and lakes formerly lay.

I may add, that it would appear from the Roman historians, that London, at the same time, was surrounded by woods and marshes; and it is probable, that the extensive mosses found in the vicinity of that metropolis, in digging the docks at Deptford and Blackwall, and in all the marshes adjoining, originated from these *.

SECTION V.

Many of these forests were destroyed by fire.

I WAS not a little surprised at the remark of a very ingenious gentleman, upon this subject. When I hinted to him the probability that many of the forests of Europe had been consumed by fire, he said, he doubted much whether a green growing forest would burn at all. Perhaps others may entertain similar

* Blavier mentions, that the Roman causeway was discovered under the mosses near Calais, on the banks of the Seusel river.

And Mr Aiton mentions, that the remains of this same road has been discovered under the moss of Logan, in the neighbourhood of Kincardine moss.

doubts. To these I would reply, that innumerable accidents of this kind have happened over all Europe. Whole forests have thus been consumed in a single day. Rozier observes, that before the mendicant beggars were dismissed from France, the whole country was in a continual consternation; for, when they were refused any thing they asked, they threatened to set fire to the forests, and often put these threats into execution. He adds, that shepherds, by leaving small fires burning, often occasioned similar accidents.

He mentions two instances of forests kindling of their own accord. In the parish of St Cyr this happened in the year 1774. About 50 years before that, a similar accident took place in that neighbourhood. These both stood on a subsoil of moss. To this he ascribes the accident. He supposes, either that the moss was so dry, and the inflammable air so abundant, that it caught fire; or that it was owing to the pyrites which abounded in the moss, which kindles as soon as it comes in contact with the air. By such an accident whole forests may have been utterly ruined; for he observes, that the trees thus burnt in these forests were easily overset. The soil was so dried by the fire, and the roots of the trees so loosened, that the first gust of wind overset them.

Mathiole, in his Commentary on Dioscorides, observes, that the larix trees in Norway are overgrown with a species of fog or moss which kindles on the smallest spark: That he slept one night in these woods: That the shepherds set fire to this moss;

That the forest blazed and burnt with the rapidity of gun-powder, and diffused a most delicious odour all around.

Wedelius de Musco Terrestri says, that all the mosses contain an oleaginous inflammable matter. Some of these, he observes, if speedily dried, spontaneously take fire. Hence, he adds, whole forests have been consumed; these mosses being kindled by the heat of the sun, or by lightening, or a dry warm summer.

He says, that many instances of such accidents were known to him, especially in Holland, where such conflagrations have continued for weeks, and even months.

De Vries mentions many instances near Geethorn, Beukween, and Haula.

In 1567, one occurred by the carelessness of a shepherd.

In 1541, Guicard mentions, that another took place in Brabant.

At Stavoren in Friezland, a whole forest, with all the subsoil of moss, was consumed in the year 1222, and converted into large caverns and lakes.

In 1593, when the Spaniards were attempting to form a road near Sheouerbeck, the inhabitants set fire to the morass, and it burnt with such impetuosity as to consume every thing in its way. The whole morass was thereby rendered impassable by the caverns and lakes that were formed by the conflagration.

It is unnecessary for me to mention instances of similar accidents in Britain: That a few years ago, the fir woods of Melville in Fifeshire, and a vigorous young plantation in Baldernock in Stirlingshire, were consumed by fire. I only observe, that such is the conviction of the danger of similar accidents, that salutary laws have been enacted in almost every nation in Europe to prevent them. Many ingenious arts have been devised and used to arrest the fury of the flames, or extinguish them altogether. Degner describes the means used by the Dutch; and the Marquis de Tourbillie mentions the precautions he was obliged to use in France.

That many of the forests of the north of Europe have suffered this fate, seems to me absolutely certain. Many of these that now lie in ruins under the mosses bear evident marks of this.

Carr mentions that many of the trees found in the Irish mosses have been consumed by fire.

Degner mentions, that burnt trees are often found under the Dutch mosses. De Luc observes, that many of the trees found under the mosses of the Continent have fallen a prey to the flames. Dr Boates describes similar marks of fire on the trees dug out of the Irish mosses.

In many of the mosses of Britain, in the parishes of Strathaven, Applecross, Edzel, Kilbride, &c. in Scotland, and in Hatfield Moss, &c. in England, there are similar marks of fire. In many mosses which I have examined, especially those which lie

along the line of Hadrian's wall, there are similar appearances.

The stocks of the trees are found standing erect as they grew. These are generally broken over about two feet above the level of the original soil. Great quantities of ashes are found bye these roots; and the lowest stratum of these mosses is entirely made made up of ashes. Chips of charred wood abound in it. These are not only observable by the microscope, but obvious to the naked eye. I was somewhat surprised at this when I first observed it; but the more minutely I examined the peats dug from that stratum, I was the more convinced of the truth of what I state. I have seen many beautiful specimens of these peats. In some the chips of charred wood are smaller than a goose quill. They are so closely united, that they appear like a piece of net-work. In others, they are upwards of an inch in diameter; yet all these were dug out of the very bottom of a moss, from three to six feet deep. It is utterly impossible to examine such mosses, without concluding, that the forests which originally gave birth to them were consumed by fire. The whole of the lowest tier of peat has the appearance of powdered charcoal and chips of charred wood kneaded together.

By what accident, or by whom such forests have been consumed, must remain a secret.

There are, however, many circumstances that render it highly probable that the Roman legions were

the chief actors in this scene. These I shall shortly state.

1. No one nation, at that early period, ever extended their empire over all the north of Europe, but the Romans.

2. None had therefore such means, or so many powerful motives to prompt them to destroy these forests.

3. As none had such means or motives, so none seem to have formed the resolution, or given such general orders to this purpose.

4. The only remains of the ancient forests of Europe are to be found beyond the ancient limits of the Roman Empire.

5. Over all the extent of that empire, the ruins of these forests may still be traced in the mosses and marshes of Europe.

6. In most of these, Roman antiques may still be found:

7. And in none, so far as I have heard, have any relicts of any more ancient nation been discovered.

I have, therefore, no hesitation in concluding that many, if not most of the forests of Europe, were ruined by the Romans.

Their great object was the utter ruin of these forests. It is natural to suppose that they would adopt the easiest and most expeditious methods of accomplishing their end; and no method could be more speedy and effectual than the flames. It is natural to conclude, therefore, even though we had

little or no evidence of this, that these means would be often employed.

On this subject I cannot but notice a very remarkable paper in the Phil. Trans. No 275. The subject is Hatfield Forest. The account of it I give in the author's words:

"That the Romans did destroy great woods and "forests in these moors, marshes, and bogs, I come "now to prove. The common road of the Roman "armies was from south to north, by Lindum (Lin- "coln) to Sigiculum (a little burrow upon Trent), "from thence to Donum (Doncaster) where slept "a standing garrison of Crispinian horse. On the "E. and N. E. of the road between these two last "named places lay the borders of the Great Forest. "This swarmed with wild Britons, who were mak- "ing continual sallies from the same, and retreating "to it again; intercepting the provisions of the Ro- "mans, and destroying their carriages; killing their "allies and passengers; and disturbing their garri- "sons. This at length so enraged the Romans, that "they were resolved to destroy this forest. That "they might do it the more easily and effectually, "they marched with a great army against the same, "and encamped on a great moor near Tinningly, as "appears from the fortifications that may still be "seen.

"Near this it is probable that a great engagement "took place; for hard by it is a little town called "Osterfield. Now, as *field*, the latter part of the

" word, is never used to be added to any other but " where there has been a battle, so *Oster*, the former " part of the name, seems to tell us what Roman ge- " neral it was who fought, viz. the famous Ostorius, " whom all the Roman Historians assure us was in " those parts.

" Who got the victory is not so easy to say. No " doubt it was the valiant Romans, who, besides " multitudes of the Britons whom they slew, drove " the rest into the woods and forests that covered " this low country. Wherefore the Romans, that " they might destroy the enemy more easily, took " the opportunity of a strong S. W. wind, set great " fires to the forest, which, taking hold of the fir " trees, burnt like pitch, and consumed infinite num- " bers of them. When the fire had done what mis- " chief and execution it could, the Romans brought " their army nearer, and, with whole legions of cap- " tive Britons, chopped and cut down most of the " trees that were left, leaving only here and there " some great ones untouched, as monuments of their " fury.

" These, being destitute of their underwood and " neighbouring trees, were easily overturned by strong " winds. All these trees, falling across the rivers that " formerly ran through that low country, soon dam- " med up the same, and, turning it into a great lake, " gave origin to the great turf-moors that are here, " by the girations of the waters, the precipitation of " terrestrial matter, the consumption and putrefaction

"of rotten boughs and branches, the vast increase "of thick water-mosses, which wonderfully flourish "and grow upon such rotten grounds.

"Even now, since the drainage, and since that "ground is laid dry, for many miles, they are so "surged with water, and so soft and rotten, that they "will scarcely bear men to walk on them.

"Hence old Roman coins, axes, &c. have been "found near the roots of the trees that lie at the bot-"tom of these moors and levels.

"Hence, too, on all these grounds great numbers "of trees are found burnt, some in two, some length "ways, and some chopped and hewn.

"Hence some are found with their roots, and "others, as they have lain all along, have branches "growing out of their sides.

"Hence they lie bye their own proper roots, with "their tops to the N. E.

"But, to return to the Romans, as they were the "destroyers of this forest, so were they likewise of all "the others that grew on the low countries of Che-"shire, Lancashire, Yorkshire, Lincolnshire, Staf-"fordshire, Somersetshire, &c. &c. Yea, and of the "countries beyond the seas, where such trees are "commonly found."

I may add, that De Luc, who examined these countries, gives it as his opinion, that the Roman urns, and other antiquities found in the bottom of the mosses, are evidences that these forests were destroyed by that people.

SECTION VI.

Other means by which Forests have been ruined.

WHOLE forests have slidden down from the mountains, where they grew, into the adjacent vallies. Instances of such accidents are recorded. Kirwan, in his geology, mentions a case. In the year 1787, a whole side of a hill (near Meudon in France), covered with wood, descended 50 feet into a plain, and covered it to the height of 70 feet. Its descent lasted six years.

Dr Boats mentions a similar instance in Ireland. Upwards of four acres of a hill, near Clogher, slipped down from the declivity, carrying trees and shrubs, &c. and burying them in the valley, in the year 1712. Rozier mentions a similar case in Bohemia, 1770: Part of the mountain of Zeigenberg slid down 38 fathoms, till it reached the Elbe, with its trees standing partly erect and partly inclined.

Similar accidents may have happened elsewhere. By these not only forests may have been overset, but the water or rivers in vallies may have been pent up, so as to form a morass over such forests, and give origin to mosses.

It seems probable, too, if not certain, that some forests have been overwhelmed by inundations of the ocean. Those in the Basse Somme seem to have suffered this fate. It would appear, both from Cæsar's account of that district, and from Pontus

Henterus's survey of it, that the lower part of the maritime coast of Picardy was at one period overflown by the sea, though now a moss. Not above 500 years ago, salt works existed in that district; and soda of course may still be extracted from the mosses of Picardy.

Lentilius and Commelinus both agree in the supposition that Holland was once an extended forest; that this was overflown by the German Ocean; that this forest sunk in the mud, and, by the accession of particles of earth, formed the immense mosses of that country.

Picard mentions an instance that happened at Cimmerium before the Christian æra;

And there are historical records of similar instances. Westerman mentions a case in 1230, where the sea overflowed a woody region near Stavoren, where the subsoil was moss.

Schotanus supposes, that the mosses of Friezland originated in Norway, and were carried hither by the sea; that the vallies where they now lie were forests overwhelmed by this inundation. He says, many trees are found at the bottom of these, as monuments of what they once were.

He mentions a remarkable circumstance of two lakes near Cauches. The borders of these are covered with immense oaks. These are sometimes undermined by the billows, or torn up by the tempest, and swept away like floating islands, carrying these vast trees along with them.

The submarine forests on the east coast of Lincolnshire seem to have suffered a similar fate.

These are very extensive; they reach not only over all the fenny country, but far into the German ocean; in every respect they resemble the mosses in Hatfield and the adjacent fens. Dr Alderston observes, that wherever bores have been made, moor and peat earth is found on the same level, whatever the incumbent soil on the surface may be.

Joseph Correa de Serra, in his excellent paper upon this subject, mentions the species of wood found in this submarine forest, " That it is the same " as in the adjacent fens:

" That as in mosses, so in this forest, wood is " found fit for economical purposes:

" That the trunks of many of the trees are found " flattened like the Surturbrand and Bovey coal, " by the incumbent weight of sand:

" That the trees are found precisely in the same " positions as in most of our mosses. Some are " fastened in the original soil from whence they " sprung; the trunks of others are broken over; " the bark of some is perfectly fresh, especially of " the branches; the silvery skin, or outer mem- " brane, is discernible.

" The subsoil is also similar, viz. a greasy clay. " This is covered, many inches deep, with rotten " leaves, whose form is scarcely distinguishable by the " naked eye; but when these leaves are put into

" water, they separate each from the other, *so that the* " *several species of the leaves may be discovered.*

" It is clear, that these trees are not water-borne, " but all grew upon the spot. Each trunk has its " corresponding root attached to its native soil."

As to the means by which this forest has been subdued, we can be at no loss to conclude, that it was by an inundation of the German ocean; and we must suppose one of two things; either that the surface of the sea has risen to such a height, as to overflow this forest, and lay it in ruins; or, that the soil on which it grew has subsided. The former of these suppositions is not consistent with geological facts: the latter is more probable; especially, as we know of instances where the shores of the sea have sunk many feet. At Venice, Pola, Lessa, Bora, &c. this happened. Borlaze records similar instances, too, in England; other instances might be mentioned; that in Yorkshire is well known.

I may add, that there are similar appearances on the opposite shores of the Continent; yet, from authentic evidence, we have reason to conclude, that the level of the sea, in those quarters, is the same as in Cæsar's time. The coast is still, in every respect, similar to what he describes it; the Roman ways still exist, and reach and terminate at the very spot which he points out.

So that if the sea has risen, so as to overwhelm these forests, it must have been prior to the period of his reign. Indeed, there seems strong reasons for

supposing, that these forests were overwhelmed at a much earlier period. On the coasts of Lincoln there is a stratum of solid soil above these trees, in many places 16 feet deep. To form this, would, in all likelihood, require many ages. Hence these forests are called, by the vulgar, *Noah's wood:* for they suppose that they are coeval with the flood.

It is unnecessary to enumerate all the places along the English coast, where the remains of forests are still discovered under the sea, at low water. Cambden specifies many, and Childry mentions a number. He says, that about two miles east of St Michael's mount, at low water, they cast aside the sand on the shore, and dig up turfs that are full of the roots of trees: on some of these trees they find nuts. Large trunks are also dug up by the tinners, which they suppose have lain there since the deluge.

On the coast of Cumberland, he observes, that similar discoveries are made.

He says, too, that the sandy shore on the coast of Pembrokeshire was laid bare in the reign of Henry II. by a violent storm. By this means great trunks of trees were discovered. Some of these, he says, bore the marks of the hatchet; and they lay so thick, that they seemed to be a whole forest in ruins.

Borlase mentions similar appearances on the coast of Cornwal. Great numbers of trees are found below sea-mark: especially oak, hazel, and willow: When the tide is in, these lie 12 feet under water.

There can be no doubt, that immense forests have, at one period, flourished on these coasts; and the probability is, that they have been overwhelmed by the ocean.

SECTION VII.

General Conclusions from the above facts.

First, That at one period, probably as late as the Roman invasion of these countries, *Britain and the North of Europe abounded in forests.*

The only exception to this seems to be Friezland and the Orkney Islands. The former seems to have been comparatively barren of wood, in the days of Pliny: he says, there were few trees in it; and there are few still.

The latter are described as a dreary waste, without tree or shrub. Solinus says of them "*vacant* "*homine, nec habent sylvas, tantum juncis herbis*

" *inhorrescunt, cætera earum nudæ rupes et arenæ* " *tenent.*" Torfæus gives a similar account of them in his days: he says, that in the year 890, they produced no wood; that Einar was the first who taught the inhabitants the use of turf as a fuel; that, on that account, he obtained the name of *Torf* Einar.

Mr Jamieson, who surveyed these islands a few years ago, represents them to be in much the same state as they were 1000 years ago. He says, that on a general view, " they present a wonderful scene of " rugged, bleak, and barren rocks; no tree, no " shrub relieves the eye, in wandering over the dreary " waste."

Yet these islands, as well as Friezland, abound in mosses. How these were formed, I shall endeavour to point out in my Second Essay.

Secondly, That these immense forests have fallen into ruins; some by accident, as by the tempest, or inundations of the sea; others by design, have been cut or burnt.

In place of immense forests of lofty pine and stately oaks, extensive marshes, moors, and mosses, now cover these regions: what a dreary dismal change must this have occasioned over all the north of Europe?

The fragments of these fallen forests may still be traced. The vast trunks of oak and fir found in these impassable morasses, like the stately ruins of an ancient edifice, give us some idea of the extent and

magnificence of these forests; and the marks of fire and steel point out the cause of their ruin.

Thirdly, That these ruined forests have laid the FOUNDATION *of* MANY *of the mosses of the north of Europe.*

This conclusion may appear to some more dubious: it is of importance to establish it. I shall, therefore, shortly state a few of those facts and circumstances which have led me to form it.

1. Many mosses now occupy the place of these forests. To be convinced of this, let any one read De Luc's minute detail of the mosses on the Continent, and compare this with the delineation of these countries by Ptolemy and Ortelius, or the Roman historians of that age, and he must conclude that this is the case. The very site of a great part of the immense forests of Hircinia, Semana, Ardennes, &c. is now occupied by mosses and moors, by fens and lakes.

2. Trees are found in most of the mosses of Europe. In nine-tenths of the British mosses they abound: of this I need not adduce evidence.

The same is the case with the Irish mosses. Dr King says, that "*trees are generally found at the* "*bottom, not only of the wet, but even of the dry red* "*bogs.*"

In the preceding pages, I have shewn, that the same is the case with most of the mosses in France.

I only add, that Blavier was so struck with this, that he says it is probable that all the French mosses were once forests. Ribaucourt also makes a general remark, that there is scarcely a valley in France without moss; that under this moss, wood is found.

Even in Holland, immense trees are found in many mosses, though not in all. Is it not natural to conclude that these mosses, for the most part, are the remains of ruined forests; otherwise, how came these trees to be found in them?

Degner tells us, that some of the Dutch suppose that these have grown up like subterraneous plants, after the manner of minerals and fossils: is not this directly contrary to the laws of vegetation? When was it ever known, or where was it ever seen, that a stately oak or fir was found growing in the deep caverns of a lake? Even supposing they had sprung up there, how have they been cut and burnt, &c. as they are often found? Have these caverns and subterraneous regions been peopled with inhabitants? Have their coins and hatchets, and other utensils, been so similar to the terraneous inhabitants, as not to be distinguished from them? Have they needed fuel? And, have their fires been kindled and kept alive in these lower regions?

He tells us farther, that others suppose that these trees have grown above the marsh, and sunk by their specific gravity to the bottom, where they now lie. If they grew upon the marsh, how have their roots been fixed to the subsoil, even of the deepest of these

morasses? Is it possible to conceive that a tree, by sinking in a marsh or lake, should strike its roots and tenderest fibres deep and wide into a solid mass of clay? Is it not much more reasonable to conclude, that this clay was the native soil from which the tree first sprung?

He adds, that others suppose these trees to be water-borne; that they have been carried by inundations of the sea, and lodged in lakes and mosses. That this may have happened in some cases, I have already shewn: that trees may have sunk in the ocean cannot be doubted. Dr Watson proves, by a number of simple experiments, that wood becomes specifically heavier than water after being steeped in it. A piece of fir, steeped 100 days, sunk in water at 60 degrees; oak and ash sunk much sooner. But, if all the trees in moss have thus been water-borne, how comes it that, in almost every moss, the trunk is found lying bye the root? Did these trunks, after performing their voyage, like dutiful children, return to be buried in the same grave with their parents? And how did each species, by some elective attraction, or magical charm, after being huddled together, return each to its proper soil, the oak to the clay, and the fir to the sand, from which they sprung?

Dr Anderson gives a still more learned, though not less ludicrous, account of the matter. He concludes, not only that moss is a plant *sui generis*, which continues to increase to an immense magnitude and indefinite age, but that, in its progress, it

envelopes trees and every other matter that comes in its way; and, in a learned note, he endeavours to shew, that this is nothing contrary to the course of nature; that similar instances of extraneous matter in growing vegetables have been discovered. He mentions two; the first is a hazle nut, found quite fresh, near the heart of a large beech tree; the second is a knife, found also near the heart of a large fir tree; and he endeavours to shew, that these cases are quite analogous to wood found in moss. He carries on the analogy still farther, and endeavours to shew, that animal matter, and even animals, have been preserved alive in the heart of trees; that this also is analogous to moss; that the carcasses of animals are found inclosed in the same manner, and preserved in the same state, in that substance; but that this is no proof that the trees found in moss grew upon the spot. His words are, "*It is true that wood is sometimes found* "*in moss, and it is equally true, that flies are found* "*in amber; but does it follow from hence that amber* "*is produced from decayed flies?*"

I shall not presume to follow up the Doctor's reasoning, nor attempt to trace the analogy he endeavours to establish; I only observe, that moss has been supposed to be a growing vegetable, *sui generis*, nearly a century ago, by some of the Dutch: That this hypothesis may be wholly the Doctor's own, as he insinuates in his preface, but that it is by no means new: That as it appeared at first to him (as he ac-

knowledges) only a *jeu d'esprit*, it is but fair to let him enjoy his own sport in his own way. I shall therefore dismiss this new species of vegetable from the list of plants, till its habits and qualities are distinctly ascertained. I would only suggest, that of all devouring monsters it must be the most dreadful, according to the Doctor's account; for, as I shall shew, ploughed fields, large trees, loaded boats, men and women, and the largest animals, houses, nay, streets and whole cities, have been swallowed up in its all-devouring jaws.

3. Most of the trees found in moss must have grown on the spot where they lie. Of this there can be little doubt.—The following facts will satisfy the reader of this.

The same species of trees which abounded in the ancient forests of Europe, are still found lying in ruins in moss. Pomponius and Pliny both agree that the fir, the oak, the birch, were the most prevalent in their days. Dr Guthrie states, that the same species form the greatest part of the Russian forests at present. It is unnecessary to prove that, in all the mosses of the north of Europe, the ruins of these species are found in the greatest abundance. This clearly proves that these mosses have been formed of the indigenous plants that prevailed, and still prevail, to grow on their native soil; that this congeries of vegetables has not been water-borne, or brought from remote regions or distant climes.

But it is equally certain, that the trees generally found in moss have flourished and decayed on the very spot where they are now found.

For, in the *first place*, Each species is now found lying prostrate on the very subsoil which is peculiarly adapted to its growth; if the subsoil of moss be clay, oak is the most abundant; if sand, fir prevails.

Secondly, It is well known that, in low warm levels, trees arrive at a greater size than on high mountains, or in colder regions; and that the size of trees diminishes in proportion to the height of the surface on which they grow. Dr Walker accordingly observes, that, in all the mosses of Scotland, the largest trees are found in the low-lying level mosses; and that the higher the mosses lie, the trees are proportionally smaller. Mons. De Luc makes a similar remark with regard to the mosses of the Continent. And both agree that this is a strong presumptive proof that these trees grew on the spot.

Thirdly, The trunks of many trees found in moss are still attached to their roots; these roots are fixed in the subsoil. Even when the trunk is broken off, it is generally found lying prostrate, near the parent root, which stands fixed in the native soil. These trees are often found standing erect as they grew. In many of the deepest mosses on the Continent this is the case: in the Isle of Man, especially, in the Marsh of Curragh, vast trees are discovered standing firm on their roots, though at the depth of eighteen or twenty feet below the surface.

Fourthly, All the roots of trees found in moss are thus fixed in the subsoil; they are seldom or never found lying loosely huddled together, or lying topsy-turvey, as if they had been water-borne. Accordingly Lord Dundonald observes, that this is a proof that the moss in which they lie neither gave birth to nor supported these trees, but the original subsoil; and that the ruins of these gave origin to, and furnished the materials for, the moss which now occupies their place.

Fifthly, The leaves and fruits of each species are found immersed in the moss along with the parent tree. The leaves and acorns of the oak, the cones and leaves of the fir, the nuts, &c. of the hazel, are all found huddled together in one mass on the spot where they grew. It is almost unnecessary for me to add,

Sixthly, The upper side, or surface of trees found in moss, is uniformly most consumed. An oak may be often seen where the upper half is so consumed that only the semi-diameter of the tree remains: this is a proof that such a tree, when it fell on the spot, had been half immersed in the mass of ruins; that half has been thereby preserved entire.

4. Instances are recorded in which wood has been converted into moss, or a bituminous substance similar to it, equally inflammable, and possessing all the other qualities of that substance. Dr Anderson denies this. I shall therefore mention a few cases in point.

Cordiner, in his Antiquities of the North, mentions a case. In describing Mar Forest, he says, "that part of the woods being fallen into decay, "ranges of vast trunks of trees, which have long "lain along the ground, are immured in moss. Their "perishing leaves, and dissolving branches, strewed "around, constitute the present soil, and are in "a great measure turned into one general mass of "vegetable earth.

"In some places where water has stagnated a-"mong the fallen trees, the morass is complete and "inaccessible; in others, the trunks are so com-"pact and firm as to afford a safe and dry path, only "now and then the specious heath gives way be-"tween the logs."

He adds, "of some trees one end may be dug "into peats, and the other sawed off and used as "good timber."

Dr Walker mentions another case of the wood of Drumlanrig, and the Earl of Cromarty speaks of another near Lochbroom. The Doctor says that this forest was overset by a storm about 60 years ago. Being neglected, and suffered to remain as it fell, it rotted on the ground; so that now the whole is nearly ripened into peat earth.

The case mentioned by the Earl of Cromarty is well known. It cannot but be interesting to the reader. I shall therefore state it in his Lordship's own words. He says, "That, in the year 1651, "when he was yet young, he visited the parish of

"Lochbroom in West Ross: That he there saw a "small plain covered with a standing wood of fir "trees: That they were then so old that they had "dropped both their leaves and bark: That he had "occasion to visit this forest fifteen years afterwards: "That, by this time, there was not a tree to be "seen: That the plain was covered with green moss: "That, in the year 1699, he saw that the whole "was converted into peat moss, from which the in-"habitants dug peats."

I may add that,

5. The names of mosses imply that they have originally been woods.

There are innumerable instances of this both in the British Islands and on the Continent of Europe. Immense tracts of moss, in which there is not a single blasted trunk of a tree standing, bear still the original name of wood or forest. This clearly proves, that, at the period in which they obtained that name, they were not mosses but forests; and that they retain still that name though in ruins.

It were an easy task to enumerate a variety of instances of this that have come under my own observation. It appears to me more satisfactory to observe in general,

First, That all mosses which bear the name of *wood*, *bank*, *shaw*, *calder*, &c. are of this description.

Secondly, That the names of many mosses indicate not only that they were once forests, but dis-

tinctly bear the name of the particular species of tree which prevailed most. Of this description are all mosses which bear the following names, OAK*shaw*, ALLER*bank*, ASH*wood*, BIRKEN*head*, ALLER-*trees*, &c.

Thirdly, That all mosses in Britain and on the Continent, which are called forests, may be included in the above list. Many such lie along the line of Hadrian's wall. Easter forest, Wester forest, and Middle forest, &c. are the names of different districts where no vestige of a forest remains, excepting the vast trunks that lie in ruins in the adjacent mosses.

Fourthly, *Wolde*, *woed*, *wode*, *waelde*, all mean the same thing. They correspond to our English word *wood* or *forest*. All mosses on the Continent which bear this name, such as the Seven Wolden of Friezland, &c.; and those in the British Isles, such as Lincolnshire Woldes, the Waeldes of Kent, &c. &c. may be included in the above list.

Fifthly, Innumerable mosses on the Continent are called *holt*, or *hout*, or *boom*, or the names of them include these monosyllables. All of them signify the same thing, viz. *wood*. *Holland* or Holland is the *woody country*. *Boomen*, &c. &c. signifies the same.

Lastly, The names of many mosses on the Continent are descriptive of the particular species of trees which prevailed in the forest while it stood, and which may now be traced in its ruins. *Note*-boom is the *hazel* or *nut-tree*: *Elzen*-boom is the ash; *Eyken*-boom the *oak*: *Piin*-boom the *fir*: *Birken*-

boom the *birch*: *Kien*-boomen the *pine*, &c. &c. All the mosses, therefore, bearing these names, must have not only been originally forests, but forests abounding with that distinct species of tree whose name they bear.

If all the mosses included in the above list, or bearing such names, or names of similar import, be allowed to have been at one period forests, we may conclude that the half, or perhaps the greater part of the mosses of the north of Europe are of this description.

From all these considerations combined, viz. That many mosses now occupy the place where forests once stood: That trees are found in most of the mosses of Europe: That most of these trees clearly appear to have grown and decayed upon the spot where they now lie: That there are instances recorded wherein ruined trees in forests have been converted into moss: and That many mosses still bear names which indicate that they have once been wood: from all these considerations combined, I hesitate not to conclude, that ruined forests have laid the foundation of many of the mosses of the north of Europe.

It seems equally natural to conclude from what has been stated,

Fourthly, That some of these forests have been ruined by the Romans; and that the mosses formed on these ruins are of no earlier origin than the age of Julius Cæsar.

I say some, not all. There are mosses, no doubt, of very ancient origin: perhaps some may be coeval with the flood.

Part, too, of the moss may have been formed before these forests were overset. I have already mentioned instances in which two or three feet of moss was formed at the roots of the trees of a forest before these fell into ruins.

In all probability this has been the case in general.

But some, if not many mosses, seem to have been formed within 2000 years.

1. It is probable that all those in which Roman coins, axes, arms, and other utensils of that nation have been found, are of no earlier origin. It is remarkable, that of all the antiques found in mosses, by far the greatest *part are Roman.* No coins nor utensils of any other nation, so far as I know, at least none that would lead us back to a more remote period than the Roman invasion, have ever been discovered. The only exception to this that I have heard of, is that of a Phœnician canoe that was said to be found in moss.

Of this description are many mosses over the north of Europe. The mosses of Kincardine, Annandale, Ochtertire, Kirkmichael, &c. in Scotland; of Hatfield, Lancashire, Lincolnshire, and Cornwal, &c. in England; of Kedinger-moor, Picardie, and near Paris and Calais, in all of which Roman antiques, or relicts of Roman works have been found, are pro-

bably of no earlier origin than the age of Julius Cæsar.

2. It is equally probable, that the mosses that lie along the line of the great Roman road are also of this description. If Severus and other emperors gave so strict orders, and made such great exertions to cut down and destroy all the forests in the conquered provinces, it is more than probable that those which lay in the direct line of their march would be the first to fall a prey.

I have examined one district. I shall give a short detail of facts, chiefly with a view to induce others to make similar inquiries and satisfy themselves.

I live in the immediate vicinity of Hadrian's wall. All along that line, from the Frith of Forth to the Clyde, there is a continuation of mosses on the south and north of that wall. In most of the vallies, these mosses are obvious to the eye: they appear still on the surface: they have never been brought into cultivation, or converted into soil.

A great part of these vallies, however, are now rich meadows or arable land: Yet all along the banks of the Kelvin and Carron, these low lands lie on a *subsoil of moss*. Whether they consist of meadow, or pasture, or arable land, this is generally the case. After passing through the soil or sward, on the surface, which is from one to two and three feet thick, you come to four or five or ten feet of moss.

Through all this extent between the two Friths, the surface, for the most part, is waving; that is, it

consists of alternate hills and vallies. Yet in all these vallies, and even on the summits of the hills, if they be level, moss either forms the surface or subsoil. From the declivities it has indeed been washed away; on them little moss now appears; yet even on many of these sloping hills, which have submitted to the plough, there are evidences that wood once grew, and that moss once existed. The soil is still, in many places, a mixture of moss and clay. Many roots and trunks of trees are still dug up from time to time.

These remarks are not limited to one parish or county only; they apply to many. In the parishes of Falkirk, Slamannan, Cumbernauld, Monkland, Kirkintilloch, Cadder, Kilpatrick Easter and Wester, Renfrew, Paisley, Kilbarchan, Kilmalcolm, that is, all along the south of Hadrian's wall, these traces are to be seen; in Airth, Larbert, Denny, St Ninians, Kilsyth, Kippen, Campsie, Fintry, Baldernock, Strathblane, Drummond, and Bonhill, on the north of the wall, they are equally conspicuous.

A superficial observer may overlook these. As he passes along he sees few trees, and none of the remains of our ancient forests. He would never call this district *horrida sylvis*. Here and there he would discover a tuft of moss or heath, a trifling lake, or extended morass. The rich vallies would arrest his attention; the extensive meadows would please his eye; but, upon a closer inspection, he would find, that all these lie on a subsoil of moss. These mosses, too, all exhibit evident marks of their origin. The

trunks of large trees found in them shew that they were once a forest. Many of these trees, too, bear marks of their having been cut or burnt. The conclusion from this is natural, that as Britain was described, in the days of Agricola, to be hideous with forests; as these forests were industriously destroyed by the Roman legions, it is probable, that those which lay along the line of their march would first fall a prey to their fury; and it is probable, also, that many of these mosses, in the line I have described, were of no earlier origin. Were this allowed, it would include a considerable extent of moss.

But the same remarks apply to the whole mosses that lie along the Roman road, both in Britain and the Continent. The same traces have been discovered, accordingly, through the parish of Strathaven, &c. in Scotland. The same are still more distinctly marked, as I have already stated, p. 50. in the low countries of Cheshire, Lancashire, Yorkshire, Lincolnshire, Staffordshire, Somersetshire, &c. &c. in England. It is not to be expected that, in every stage of the Roman itinerary, such traces should now be detected; nor is it possible to point out the particular spots which were covered with wood, and those which were morasses, at that period.

It deserves, however, to be observed, that there is not one vestige remaining of the ancient forests which Cæsar describes, along the whole line of the Roman way, excepting in the mosses where the vast ruined trunks of trees now lie.

Cæsar landed at Portus Ritupenses. Round that spot, still the level lands all lie on a subsoil of moss. The probability is that, at that period, these levels were either morasses or woods.

He next directed his course to the Thames. The banks of that river were then impassable morasses, or impenetrable forests; now they are extensive meadows, or arable lands: yet, on either side of the river, the subsoil is moss; and large trunks of trees are dug out of this.

Through Suffolk, Norfolk, Lincoln, and Yorkshire, similar traces may be seen; the Roman causeway passes through the woods which are still standing, and the fens and mosses which probably were forests at that period.

In Lancashire, extensive forests stood at that period. These lie now in ruins, in the immense fens of that district. Chatmoss, Penwortham, Pillens mosses, &c. are probably the only remains of these forests.

Bodotria is supposed to be Fifeshire. Agricola engaged and obtained a signal victory over the natives in that kingdom; and Tacitus says, that the woods and fens covered the flight of the enemy. Though no traces of these woods can now be seen, yet, in the mosses of that county, the ruins of them can yet be detected. Within two miles of Lochleven there is a large morass, where there has been an extensive wood: and there are still the remains of a Roman camp, in the lands of Sir John Malcolm, hard bye this spot.

The probability is, that all those mosses, whose names indicate that they were forests, were ruined at that period; and, of course, are of no earlier origin; those, on the contrary, whose names bear that they were morasses, are of an earlier origin. Horsely and Dr Stukely both agree, that the word *car* signifies a *fen*. Mosses, therefore, whose names begin with this monosyllable, were probably morasses at a very early period. I need not add, that there are the same appearances in France and Holland.

It deserves, however, to be mentioned, as a very singular confirmation of this conclusion, that in Britain, in proportion as we advance northward, the traces of our ancient forests become more entire. Beyond the boundaries of the Roman empire, in Aberdeen and Inverness-shire, &c. where their arms never reached, in these districts alone the stately fragments of these forests still remain, as the sad and only relicts of their departed glory.

The same remark applies to the Continent of Europe in all its extent. Where are the lofty pines and stately oaks now to be found?—Where but in those regions which the Roman eagle never reached. In the remote circles of the German empire, in Poland and Prussia, and still more in Norway and Sweden, and the vast empire of Russia, there and there only can we see what Europe was, before it yielded to the power of Rome.

And could the art of man restore these ruined forests that lie buried in moss to their pristine glory,

what beauty would smile around every nation of Europe, where nothing but dreary wastes and dreadful desolation now reigns? What a barrier would these forests afford against every invading foe? What a source of national wealth and national greatness would they prove?

It is demonstrable that there is more oak lies buried in moss than would supply all the navies of every nation of Europe; and that there is more fir lying there, as a useless waste, than would answer every economical purpose which it can serve.

3. It is more than probable, it is almost certain, that wherever the Roman way can be traced under moss, especially when it appears, from authentic records, that wood existed upon the spot at the period of the Roman invasion, that the moss formed over that road is of no earlier origin. Instances of this have already been mentioned; many more may exist, though not recorded or known to me. There seems to be little doubt that Kincardine and Hatfield mosses were forests at that period; they, therefore, come under this description.

In the former of these, the Roman way has been traced; eight feet of moss has been formed over it. The conclusion is, that all this has been formed since that way was laid. In the moss of Hartfield, near Paisley, in the valley of the Somme, and near Calais, also in France, in Moss Logan, &c. &c. similar discoveries of that way have been made; and it is natural to form a similar conclusion as to these mosses.

When I mentioned this to an ingenious friend, he replied, that perhaps the Roman way was formed not before, but after the moss; and that it had sunk in this soft subsoil. In some places this may have been the case; it seems, however, clear and unquestionable, that Kincardine was a forest in which little or no moss existed at that period: for the road is not only formed of the wood, but the marks of the axe may be seen in the roots of the trees which are fixed in the solid subsoil of clay; besides, the road lies on this subsoil, without any moss below it; whereas, had it been originally laid on moss, and afterwards subsided, that moss, though compressed, must still have been discovered below the road, which is not the case. The eight feet of moss, therefore, which lies above this road, must have grown after it was formed, or since the reign of J. Cæsar. I only add,

Fifthly, That some mosses appear to be of much more recent origin than those I have mentioned.

I need not allude to Cordiner's account of Mar forest, which seems to be forming into moss; nor need I repeat what is said by Dr Walker and the Earl of Cromarty, of the mosses of Drumlanrig and Lochbroom.

There are other mosses that bear evident marks of recent origin. Mr Aiton, in his essay, shews that there is strong ground to believe that the forest of Paisley existed in the 12th century. In the charter of the foundation of the monastery there, the Great

Steward conveys to the monks the tithes of all the lands *below the forest of Paisley.* He says, that as late as the year 1460 and 1524, the tenants of Dunscaith-wood, in the vicinity of Paisley, were bound by the abbot *to keep the wood or forest, and to uphold and repair the dike round it;* yet, at this moment, there is not a vestige of that forest remaining, excepting the names Linwood, Fullwood, Woodhead, &c. &c. an extensive moss, many feet deep, over the low grounds, where it must have stood.

The probability is, that all this moss has been formed on the ruins of that forest, in the course of two, three, or four centuries.

The same author states it as probable, that the mosses in the upper parts of Strathaven and Avondale were of no earlier origin. This district formed a part of the forest of Selkirk. That forest seems to have extended over the upper parts of Ayrshire, Clydesdale, Peebles-shire, &c. It is ascertained that it existed as a forest in the 12th century. In the year 1180, Walter, the Grand Steward of Scotland, granted a charter to the Cistertian monks of Melrose. In that charter, he grants them in *pure alms* the whole pasture of this forest, as far as the marches of Douglas, Leshmahagow, and Glengivel; yet, in all that extent, there is not a tree remaining which can be considered as a relict of that forest. Four-fifths of the surface is covered with moss; and there is no other traces of it, excepting the names of Harwood, Neitherwood, Woodhall, &c. &c.

The conclusion he draws, is in the following words: "When I consider that the moors of Muir-"kirk and higher parts of Avondale formed part "of the forest of Selkirk, which is well known to "have existed in the 13th and 14th centuries; when "I look at the charter above quoted; and when I "find a great proportion of the land in these regions "still named by *wood* in the Saxon language, I am "warranted to conclude, that the parishes of Sorn, "Muirkirk, and the higher parts of Strathaven and "Leshmahagow, Douglas, &c. now almost wholly "covered with moss, were all growing forests at "and after the end of the 12th century."

Dr King, in his account of the Irish mosses, mentions several instances where there appears the clearest evidence of their recent origin. I name one. "There are many bogs of late standing in Ireland. "When O'Donald and Tyron came to the relief "of Kinsale, they wasted the country, especially "as they came through Connaught, which, by "means of the Earl of Clanrichard, was generally "loyal; and there is a great track of land now a "bog that was then a ploughed field. There re-"mains the mansion-house of my Lord in the midst "of it."

Dr Boates, in his Natural History, likewise mentions, that many of the Irish bogs seem to be of recent origin: he states the following instances: "Under a bog, five or six feet deep, a proper soil, "with the marks of the plough, and the form of

" ridges, were discovered." He adds, " That there are " few bogs removed but bear similar marks; particu- " larly in Armagh, Dundalk, Londonderry, Donne- " gal." He says, " that in the latter a plough was " found very deep in the bog, and a hedge with " wattles standing, five or six feet deep." He mentions, " that there are reports that the streets and " footsteps of a large town may be traced under a " moss in the north of Ireland."

M. De Luc mentions an instance on the Continent which also deserves attention. He says, that in digging a ditch in Davels moor, at the depth of four feet in the moss, was found the subsoil: that this formed an inclined plane. In this was found a trough or water-run, made of planks of wood, which shewed that it was a mill-trough. In the sand near this trough a wimble was also found. He says that he saw it, and that it differed nothing from a carpenter's wimble.

Here, he observes, is not only four feet of moss of recent origin, but a much greater depth; for all the lower level, at which this trough terminated, and in which the mill stood, is covered deep with moss.

It is almost unnecessary for me to observe, that the introduction of mills is of a modern date in Europe, and that the probability is great that the above moss is of very recent origin; it must have been posterior to the erection of that mill.

The above named author adds, that he has no doubt but, on a careful examination, many other

instances might be found, in proof of the recent origin of moss.

The rapidity with which moss might be formed and accumulated, in an extended level, is great.

An instance of this is mentioned by M. De Luc: near Bremerford there is a vast plain of this description. In that plain there is a village called Islerheim. The place itself is called Islerberg, or the town in the isle, or rising ground; yet he observes the whole is now a horizontal plain. At the time it acquired its name, and probably, when the village was first established, this spot must have been a rising eminence like an island; yet that appearance is gone; the adjacent moss has now risen to the level of its summit: so that what was once an island, has now disappeared, or rather it is now on a level with the adjacent moss.

As a proof of the recent origin of many mosses on the Continent, he makes a general remark, that the names and terminations of many places are German; that these are descriptive of the topography of the country. Of this he mentions four instances: *vorde*, *berg*, *holz*, and *thal;* the first signifies a *ford* the second a *height* or eminence, the third a *forest*, and the last a *valley;* hence these names are prevalent in many mosses. Bremerford, Ottesberg, Osterholz, and Lilienthal, he quotes as instances of this. These being all German names, he observes, is a proof, that the origin of the mosses,

which occupy their place is comparatively recent; that is, since the German language was introduced: That, at the period they acquired these names, fords, eminences, forests, and vallies, occupied these regions, which are now covered entirely with moss.

According to Pontus Henterus, the mosses in the lower parts of Picardy, along the sea coast, are of recent origin; he clearly makes it appear that these were overflown by the ocean at the distance of 500 years; and he attempts to prove, that salt works existed at that period where nothing but an extended moss now appears.

SECTION VIII.

Objections to the above hypothesis.

I AM aware that formidable objections have been made to this hypothesis.

Degner and Dr Anderson have both combated it with great keenness: the former sums up his objections under the following particulars:

"1. That it is contrary to the common opinion of "the inhabitants of Holland.

"2. That trees are not found in every moss.

"3. That trees are often found buried where no "moss is formed.

" 4. Where trees abound, there are fewest mosses: " That they seem rather to retard than to expedite " the formation of moss.

" 5. That some mosses are found to be thirty feet " deep before we reach the wood: That it seems in- " credible that such immense quantities of that mat- " ter could be formed of wood: That the largest " and thickest forest could not supply materials suf- " ficient for the purpose: That one single acre of " moss contains more inflammable matter than twen- " ty acres of the finest forest.

" 6. That if forests are converted into moss, the " greatest part of Muscovy, Tartary, America, and " other woody uncultivated regions, would, long ere " now, have undergone that change, which is not the " case."

From all these considerations he concludes, " *that* " *moss is not formed of decayed wood.*"

The latter sums up his objections in stronger language, and marshals them in more formidable array. I shall state them, as they appear in this essay, in all their collected force: They may be reduced to the following heads:

" 1. That all vegetable substances, when dead, " decrease in bulk so much that they occupy not " above one hundredth part of the space they did.

" 2. That moss produces few vegetables; that " these tend rapidly to decay.

" 3. That the vegetable substance which forms " moss must therefore have been *one hundred* times " more bulky than the moss itself.

" 4. That mosses are found thirty, even forty feet " deep.

" 5. That the most abundant crop, on the most fer- " tile soil, will not cover the earth, when fresh cut, " half an inch deep; that, when rotten, it only co- " vers the earth one hundredth part of this.

" 6. That, therefore, it would require nine thou- " sand six hundred years to form a moss twenty feet " deep on the most fertile soil.

" 7. That moss produces not *one hundredth* part " of the crop of a fertile soil; therefore, it would re- " quire upwards of *nine hundred thousand years* to " produce twenty feet of moss earth on such a soil."

From all which he draws the following conclusions, and retires in triumph:

" Nothing can be so absurd, nothing so contra- " dictory to reason, and every known fact respecting " the decomposition of vegetables, than the whole of " the doctrine that has been implicitly adopted re- " specting the formation of moss, by means of decay- " ed sphagnum, or any other plant whatever."

This seems to me to be the sum of his objections: They are plausible, and seemingly strong; but their strength will appear imaginary, when brought to the test.

I shall endeavour to obviate these objections. My animadversions may appear severe; they shall be

made with candour. All the apology I plead is, that in the pursuit of science, and especially in the prosecution of a subject hitherto much neglected, and little known, *there is no beaten track in which we are all bound to tread.* On such a subject, we ought to set out with this motto, *nullius jurare in verba magistri*, otherwise there is an end to all fair investigation *.

The whole of his objections resolve themselves into one general point,

That if moss be formed of decayed wood, or any other vegetable substance, it must require an immense time to its formation. This, too, is the amount of Degner's fifth objection. As it is the most formidable at first appearance, I begin with it.

Let us suppose, for the sake of argument, (and the supposition will not appear absurd after what has been already stated) let us suppose, that what is now a moss was once a forest: Let us also allow, what the Doctor asserts as a well known fact, "that the thickest wood that ever grew, would not form a solid body above two or three feet deep over the surface on which it stood;" or, in the words of Degner, "That one single acre of moss contains more inflammable matter than 20 acres of the finest forest."

* Few men have displayed more public spirit than Dr Anderson; and still fewer have devoted more of their time and talents to promote the interests of his country. If any expression that drops from my pen appear disrespectful, it is not intended. On the contrary, I feel, and ever will avow, great respect for him as an author.

Even upon this supposition the hypothesis I have suggested may be supported. There are a variety of considerations that come into the account, which seem to have been entirely overlooked by the ingenious Doctor and the learned Dutchman ; the age of the forest, the annual accession of leaves, and seeds, and boughs, it must have yielded during all the period of its growth : the bark, and rind, and roots, after it was ruined, also must have added greatly to the mass of vegetable matter.

I shall endeavour to state, and follow up the Doctor's argument upon this supposition. Even upon his own *datum*, " That the thickest wood that ever " grew would not, when overset, furnish two or " three feet of moss," I hope to show, that the hypothesis I have endeavoured to support, is neither so absurd, nor so contradictory to reason, and every fact, as he asserts.

I. In the *first place*, The age of the forest must be taken into the account.

Many of our mosses certainly contain the ruins of aged forests ; trees of an immense, nay almost incredible size have been found in them.

In Hatfield moss, which we have endeavoured to show was a forest 1800 years ago, fir trees have been found above ninety feet long, and sold for masts and keels of ships ; oaks have been also discovered there upwards of 100 feet long. In No. 275. of the Phil. Trans. an oak is mentioned of the following dimen-

sions; one hundred and twenty feet long, twelve feet diameter at the root, and six at the top. No such tree exists now in the British dominions; perhaps few, if any, in Europe can be found equal to it. Twenty pounds Sterling was offered for it, which shews that it was in a state of tolerable preservation. A fir tree is mentioned by the same author no less than a hundred and fifty-three feet in length, and of proportional thickness.

Even in Scotland, and the higher regions of it too, where a tree will scarcely now strike root, some have been dug out of the mosses of very large dimensions. Mr Aiton speaks of an oak tree, dug up in the parish of Kilbride, upwards of sixty feet long, and, at the upper end, four feet circumference.

These stately plants, which now lie in ruins, could not have rushed up in a season, an age, or a century; they must have survived many generations of the human race. Upon a rough, but moderate calculation, we may suppose that such a fir would require some centuries to grow to such a size, and such an oak perhaps 1000 years.

Mr Tait, in his account of Kincardine moss, not only mentions the size of the oaks dug up, that some were fifty feet long, and three feet in diameter, but adds, that 314 circles, or years growth, were counted on the roots; yet some trees were larger: he speaks of one four feet, and another fifteen feet diameter at the surface of the clay.

All these shew, that mosses contain the ruins of aged forests.

Taking this for granted, it leads us on to considerations of great importance in the calculation; for,

II. In the *second place*, Every tree sheds its leaves annually. The oak has an abundant foliage; that of the fir is still more bulky. Where a forest is thick, as has unquestionably been the case in many of our mosses, the crop of leaves which it must have yielded annually, must have been equal in bulk to the richest crop of wheat on the most fertile soil.

Yet all these leaves must have dropt annually, during all the period in which the forest grew; say that this was only 500 years: even upon this supposition, the mass of vegetable matter thus formed must be very great.

Besides this, we cannot suppose that these leaves would cover the surface equally: each leaf would not drop to the root of the parent tree. Tossed by the winds and tempest, or washed down from declivities by the torrents, they must have been deposited in the sheltered corners, and deepest hollows of the woods; there, it is natural to conclude, they would be amassed annually in heaps; and while the declivities and eminences were stripped of leaves, these hollow levels would become the general depot of the forest.

I have often seen a mass of leaves, tossed by the winds into the hollow places of a wood, upwards of

a yard deep. Supposing that these, when they decayed and were compressed, would only furnish one quarter of an inch deep of materials for forming moss; even, on this supposition, we may account for a considerable depth of moss during the growth of any forest, at least in these hollow places; and it is only in low levels where deep mosses are found.

All the above mass was only the produce of one year. If the forest be allowed to have stood for 500 years before it fell into decay, these leaves, according to the above calculation, by dropping annually during all that period, would furnish materials for nearly twelve feet of moss, if annually accumulated in the same hollow.

It would tend greatly to illustrate this point, if we could shew that leaves have actually contributed to form moss in these hollows. From the accounts that we have of the mosses of Holland and France, Brabant and Britain, this seems to be the case.

I have already shewn that leaves have been discovered in Hatfield moss; that the several species may be distinguished. The same author who mentions this adds, "that many inches of the lowest "tier of moss consists of rotten leaves."

Similar appearances present themselves in Kincardine moss. In the Encycl. Brit. it is stated, "that "between the moss and the clay there is a stratum "*nine inches* deep, of a dark brown, or blackish "colour; that this is the remains of the leaves, &c. "of the woods before the moss was formed." Dr

Collet observes, " that the lowest tier of Berkshire " moss abounds with leaves," &c.

In the French mosses similar discoveries have been made. Demoustier, in the Journ. des Mines, mentions, that, in digging the foundation of the Pont de la Revolution at Paris, a kind of moss was found below the level of the river, divided into leaves and rubbish of vegetables, clearly distinguishable; that it exhaled a strong odour of sulphur.

De Boot says, that near Bruges, on digging fifty feet, whole forests were found; that the leaves and and trunks were so little altered, that the distinct species of the trees might be discovered: He says, even that the different series of leaves which had fallen annually may be distinguished.

Stevinus gives a similar account of the Dutch mosses, and states it as his decided opinion, " that the " leaves, &c. of fallen woods, washed down from the " rising grounds into the vallies, are, in a course of " ages, converted into moss."

In the Dict. Raisonne, similar appearances are mentioned to have been seen in the mosses of Brabant. I quote the passage in the words of the authors:

" In digging the peats in Brabant, at a place called " Pieland, they find below the sand a stratum very " hard and very compact, which is nothing else than " a mass of leaves of trees, &c.; the odour this emits, " (it is added), is insupportable: but, when exposed " to the air, this substances separates of itself into

" leaves, and one can easily distinguish that this whole " stratum is nothing but an immense mass of leaves " heaped together, and formed into a body. This " phenomenon (they add) proves, in a decisive and " satisfactory manner, the origin of moss."

Sir Joseph Banks mentions a still more striking circumstance: " He says, that he found a species of " schistus in Iceland, a great part of which consists of " leaves, evidently those of the alder, interposed be-" tween the lamillæ; that they were not the mere " impression, but the *real substance* of leaves, ap-" parently half charred."

St Fond mentions, that a similar schistus, with leaves in it, in a similar state, was discovered at Roche Sauve, in the Vivarais.

I need not add that Werner mentions that trees with branches and leaves petrified were found 150 fathoms deep, and that Rozier says that coal is sometimes discovered with leaves in it;

But I cannot pass over a remark of Dr Anderson, upon this point: he makes no hesitation in deciding, " that moss is an organized body, a growing plant, " *sui generis*;" and he mentions it as one of the " great outlines of the species, that mosses which pro-" duce the best peat, seem to be of a *foliated* texture. " When these are broken, they rise in flakes, which " have much the appearance of a congeries of leaves, " or rather hops pressed close on one another.

He adds, " that this very appearance has served " to confirm some in the opinion that moss is produ-

" ced from decayed wood, as they believe these are
" the leaves of the trees preserved; not adverting
" to this, that, by all their hypotheses, the trees have
" been felled before the moss began to be formed,
" and, of course, that their leaves must have fallen
" to the ground, and been totally consumed before
" the moss began to grow: nor would all the
" leaves produced by any wood in the course of *a*
" *hundred years*, while in a growing state, though
" they had been all preserved from decay during
" that period, have accounted for *half the quantity*
" that is found in some mosses."

I am afraid that the Doctor is inadvertent himself; not attending to this, that some, if not most of the forests alluded to, must have stood, not for one or two, but for five or ten hundred years, as I shall shew afterwards; and that the leaves of oak, fir, and birch, have been discovered, free from decay, in the deepest mosses, nay, upwards of a hundred feet below the surface of the earth, where they must have remained many hundred years, without being diminished in bulk or consumed.

But I dismiss this article, and proceed to observe,

III. In the *third place*, That every tree yields seed after its kind. The oak drops its acorns annually, as well as its leaves; the fir sheds it cones: the former are numerous; the latter are much more bulky.

During all the period of its growth, and part of the time in which a forest falls into decay, the acorns

of the oak, the cones of the fir, and the nuts of the filbert, must have annually dropt. Blended with the leaves and the ruins of many generations, they must have added to the mass of vegetable matter.

Few of these, comparatively speaking, have been discovered in mosses; but, though they have disappeared, or may still lie deep in these fens, they have not been lost. They may, indeed, have undergone a partial, perhaps in some cases a total, disorganization; yet, even in this case, the vegetable matter of which they consisted would not be dissipated in air, or evaporate entirely, but remain among the ruins, and add to the mass.

There are, however, many instances in which these have been found deep in our mosses, in an entire and organized state. I shall mention a few; the reader may recollect many more; and they ought to be recorded.

Dr Leigh, in his N. Hist. of Lancashire, mentions, that many cones of firs are dug out of the mosses of that county.

Dr Collet says the same of the Berkshire mosses.

In the fens of Lincolnshire the cones of the fir tree are sometimes found entire, No. 275. Phil. Trans.; it is added, that they are found in whole bushels.

Ramazini assures us, that in Low Modena, not only roots of trees, but nuts, ears of corn, leaves, &c. are found 30, 40, and 50 feet, below the present surface.

And Piganiol says, that, in the mosses of Holland and France, not only innumerable trees are found, but that sometimes fruit-trees are discovered with their leaves and fruits; the oak with its acorns; the hazle erect, with its leaves and nuts, entire as they grew *.

These nuts and acorns, and cones, the produce of many hundred years, must have added a vast congeries of vegetable matter, and may have contributed their part to form moss.

I may add to this,

IV. In the *fourth place*, That, when a forest is thick, innumerable small twigs rot and drop off from time to time.

It were superfluous to offer any further proof, that many of the forests that now lie in ruins under moss have been very thick set. The trunks of most of these trees are perfectly straight; they have mostly attained an immense height; their roots remain closely studded in the soil from which they sprung. All these are evidences that they must have grown closely together; indeed, it is natural to suppose that this would be the case: for, where trees drop their seeds, and these are suffered to spring up with impunity,

* Mons. De Luc, in his letter to me in January last, says, that, in the mosses in the north of the Continent of Europe, a great number of resinous trees are found, and likewise the cones of that species.

(as Du Hamel states, in the forests of Bourdeaux), they uniformly grow up in a thicket.

I may refer to the reader, or to Dr Anderson himself, whether there are not the clearest evidences that this has been the case with many of the forests found buried in moss. He acknowledges, that "in the exhausted moss of South Fanthing, the roots and "stumps of many very large oak trees are found "standing; some of these are six and eight feet dia-"meter, and yet they stand so closely together, that "they are not more than three or four diameters "distant from each other."

Now where this is the case, as Rozier observes of the forests of France, all the lower branches and twigs rot and drop off; so that we may see eighty feet of a trunk without one twig or low branch. This, too, must take place during all the period of the growth and decay of these forests; yet none of these twigs, few even of the branches of trees, are found in moss.

Leland, in his Itinerary, takes notice of this circumstance: "Oftentymes, in digging the moss or "moor of Cholmley for pettes and turves, they fynd "whole trees, some short, some veri long, without "twig or bow."

I appeal to the reader whether this be not the case in mosses in general. Upon a narrow inspection, he will find all the small twigs blended with the moss; some in an entire organized state; some half decay-

ed; and some where the disorganization is almost complete.

These twigs, with the branches, which are also found sometimes in the same state, must have added, in the lapse of ages, a great accession of vegetable matter*.

There is a consideration of still more importance:

V. In the *fifth place*, Every tree has its bark and rind.

Du Hamel, a distinguished writer on forest trees, points out the quantity of bark which each tree produces in proportion to its size. He says that the bark of a fir tree, though only half an inch thick when young, is often an inch and a half when old. The oak, it is well known, is equally remarkable for the thickness of its bark, especially when it advances to a great age.

De Luc observes, that in the mosses on the Continent no fir nor oak is discovered but what is stripped of its bark. This is generally the case in Britain; the only exception is that which I have already noticed, that the bark is often found entire, and adhering to the under part of the tree.

* It is certain that the branches of a tree are the first part of it that falls into decay; the trunk falls next to these; but, after both have fallen into ruin, the roots remain entire in the soil for a long period. It is not, therefore, surprising, that more trunks than branches, and more roots than trunks, are found in an organized state in moss.

This bark has disappeared; or rather it has been blended in the common ruin. By this means, it must have added an accession of vegetable matter, and contributed its part to form moss: this is not only a natural, but an inevitable conclusion, and that it has been the case, there is the clearest evidence.

I have seen many beautiful specimens of peat which proves this; especially those dug out of a moss in this neighbourhood. The lowest stratum seems to consist almost entirely of a congeries of bark kneaded together; the organic structure of it may still be distinguished; the fibrous form of the inner rind is visible, and, though it appears to be often broken and crumbled into chips of one or two inches square, yet the thickness of the bark can be ascertained. I have this moment before me a specimen six inches long, three broad, and upwards of an inch and a half thick, although the outer layer seems to be gone. I can distinctly count upwards of thirty layers remaining; it smells still somewhat like fir, and burns with a bright flame, emitting a very fragrant odour. It cracks when held to a burning candle.—This specimen was dug out of a moss which abounds in fir wood.

That the whole bark of the tree to which this belonged has been buried in the moss, and contributed to form a part of it, cannot be doubted; and that the whole bark of every tree found in moss, whether that bark still adheres to the tree, or be found detached from it in a disorganized state, adds an acces-

sion of vegetable matter, is equally obvious. That peat moss may be imitated, and artificial peat made of bark is certain. Degner mentions, that in Westphalia, Drenthea, Velavia, &c. they mix the refuse of tanner's bark with cows dung, and dry it in the sun. In form, colour, and weight, he says, they can scarcely be distinguished from real peat. They are equal in quality as a fuel to the middle species of moss he describes; their ashes are similar.

As to the quantity of bark any forest may furnish, it is all conjecture. But since Dr Anderson is pleased to state his objections to the hypothesis I have endeavoured to support, with mathematical precision, according to the strict rules of arithmetical numbers, I shall attempt to reply to him in his own style. My calculation may appear fanciful, perhaps incorrect; it cannot be more fanciful, nor perhaps more incorrect than his, as stated in page 83 of this essay.

In order to calculate the quantity of bark a forest may yield, let us take one tree for an example:

Suppose it be the oak of Hatfield, above mentioned; say it was 120 feet long, 12 feet diameter at the base, and 6 at the top: then take the mean diameter for the whole, call it 9 feet,—this makes the whole tree 27 feet circumference: multiply this by the length; this gives 3240 feet of surface;—suppose the bark to have been only an inch and a half thick, this gives 4860 feet of bark. All this is independent of the top and branches: allow only a moderate

quantity for these, and call the whole 5000 feet in round numbers.

Yet this tree, from its immense height, must have stood in a thick forest. It could not have covered a great surface: say that it occupied four falls of ground. Even upon this supposition, the quantity of bark is great for that space: every fall contains thirty-six yards, every yard contains nine feet: four falls, therefore, contain 1296 feet. Yet this tree, on a very moderate calculation, must have yielded 5000 feet of bark, which gives nearly five inches of solid bark to the whole surface it occupied: this is certainly more vegetable matter than a thousand crops of the finest wheat would yield, if suffered to decay upon the soil.

All this matter, too, it would yield at once, viz. at the period of its ruin and decay.

When this accumulation of bark is added to the mass of leaves, and fruits, and twigs and branches, we can more easily conceive how materials may be furnished for the formation of moss.

It is of importance also to attend to another circumstance:

VI. In the *sixth place*, That some trees in every forest decay through age: That it is probable whole forests may have suffered this fate; especially where a subsoil of moss had been formed around the roots of the trees during the period of their growth. Chilled by this means, and checked in their growth, not only the bark but the white-wood might crumble away be-

fore the trees were finally overset. This is no imaginary case; the Earl of Cromarty mentions an instance that came under his own eye. His Lordship observes, that, when he saw the forest (alluded to in p. 66.) in ruins, the "trees were all blasted, the "bark was all gone, the white-wood was quite *rotten*." Whether this all dropped off and crumbled down before the trees were overset it is not said; nor is it of any importance to the argument: for this one thing is certain, that it must soon have *mouldered* after the fall of the forest, and thus mixed with the mass of ruins.

It is equally certain, that the trees found in moss are generally, if not always, stripped of this white-wood; the red only remains: or, if any of the white-wood is to be seen, it is so soft, spongy, and porous, as scarcely if at all to be distinguished from the surrounding moss.

If this be allowed, that the trees which decay through age drop their white-wood sometimes before they be overset, and that all trees found in moss are mostly divested of it, the whole of this white-wood must have contributed its part to the formation of this substance. What proportion it may have yielded it is impossible to ascertain; it may be considered as nearly equal, if not in most cases greater, than the bark.

Hitherto, we have only considered the trunks and branches, I may add,

VII. In the *seventh place*, That the roots are also to be taken into the account. These also have their bark and rind. For the most part, the roots of trees found in moss, are stripped of both; of course, they must have added to the mass of vegetable matter. It is impossible to calculate or conceive what that quantity may have been.

But I have endeavoured to prove, that some of the ruined forests, found in moss, have been overset by the violence of the tempest, and that others have been burnt.

If this be allowed,

VIII. It must also add greatly to the account. The violence of the tempest would not only tear off many of the branches, but the sudden and tremendous crash of one tree upon another, would mangle the whole. The high twigs and branches would thus be torn and scattered about in wild disorder.

Nor would this only take place upon the supposition, that the forest yielded to the impetuosity of the tempest: when cut with the hatchet, the effect would be the same, with this additional consideration, that the chips cut out of such immense trees before they were felled would add greatly to the mass.

Above all, if it be allowed, that some of these forests were burnt, this must have added to the account. Wood, when green and growing, though it burn with fury, is not speedily or entirely consumed; that is, it is not altogether reduced to ashes; on the

contrary, a great part of it is only charred. The quantity of charr that a forest thus partially consumed may yield, we may calculate or conceive from the following statement:

Proust says, that wood, in general, yields nearly one-fifth part of carbon; that is, nearly 20 parts in the 100. The *pine* yields precisely this quantity; a green growing *oak* yields the same proportion; some species of wood yields more.

If so, what a prodigious quantity must a single tree, such as that found in Hatfield moss, produce? Let us, for the sake of illustration, give a rough calculation of it.

Say this tree was 120 feet long; call it only six feet square in all its length, though it must have been more; every running foot, upon this loose calculation, must have yielded 36 cubic feet of wood; the whole tree, therefore, must have contained upwards of 4000 cubic feet: supposing it afforded one fifth of carbon, this single tree must have yielded upwards of 800 cubic feet; and, if it occupied only four falls of ground, as we have stated, the carbon it contained, if equally spread over that surface, would cover it nine inches deep.

That charred wood has actually contributed to the formation of some mosses seems to me incontestable. As I hinted already, p. 46. some mosses I have examined bear evident marks of this; the lowest stratum seems to consist almost entirely of chips of charred wood; the fibres of the wood are still distinct;

its original form remains; it has still the clear black glossy colour of charcoal.

The peat it yields is almost as hard and heavy as coal; it burns with a bright flame; emits a great heat, and yields a lasting fire: in some of these peats the fibrous form of the wood is lost, and they appear a solid hard jet black substance, precisely similar to pounded charcoal firmly cemented together.

If we take all these into the account, we can be at no loss to find sufficient materials for a moss of considerable depth.

Hitherto we have argued upon the supposition, that there has been only one generation of such a forest; there are, however, incontestible evidences that some mosses contain,

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IX. The remains of *two, and even three generations*, each rising in succession upon the ruins of the other.

De Luc mentions several instances on the Continent, where this appears to have been the case: In Kedinger moor, he says, there are still a few trees, the fragments of the former forest. Though the moss be three feet deep, it still bears stately oaks; their roots strike through the moss, reach the subsoil, and receive their nourishment from it: these trees, he adds, must at least be the *second or third generation of that forest.*

He likewise mentions many instances where a new generation springs up on the ruins of the old; and he observes, that "when he saw the roots and ruins

" of the old trees sheltering the young, it brought " him in mind of a number of children around their " grandmother." He adds, " the seeds of former " generations had taken root among the rubbish, and " sprung up to supply their place."

Dr Walker makes a similar remark on the moss of Strathcluony: He says, " That it has formerly " been a very thick extensive fir wood: That the trees " found in it have been deposited at different periods: " That large roots of fir trees which had evidently been " broken down by the winds, are found in it: That " some of these roots, with part of the trunk in their " natural position, were found at the bottom of the " moss, fixed in the gravelly loam from which they " had sprung: That above these was a stratum of " peat, three feet thick, evidently formed during the " growth and decay of these trees: in the same " place, the old roots of other fir trees were discover- " ed, two or three feet *immediately above* the former, " with their fangs spread horizontally, having three " or four feet of moss *above them*. It was clear " that these roots belonged to trees of *another* genera- " tion, and of a date much *posterior* to the former; " for they had only begun to grow after the trees rot- " ted in the loam had decayed, and after three feet of " moss had been formed by their growth and decay." Again, he adds, " Over these last roots, situated " three or four feet deep in the moss, an aged fir " was growing on the surface:—there were here *three* " generations, or, as it were, three tier of trees visibly " placed above one another."

He concludes, "This renders it probable, that "many of our deepest mosses have been formed by "two, three, or more generations of trees, which have "grown successively above one another, at different "and distant periods."

To sum up the whole account, let us suppose that these forests that lie in ruins in our mosses had each existed only 500 years before they were finally overset; that the whole leaves they had dropped in succession for so many ages, were tossed by the winds or washed down by the waters into the low levels; that the acorns and cones, &c. the bark and rind, the twigs and boughs; the whole wood, and roots, and trunks were all accumulated in one rugged, ruinous, and unseemly group; What an immense congeries of vegetable matter must thus be deposited by this simple and certain process of nature! To make the calculation complete, let us suppose that some of these mosses are the ruins of two, three, or more generations: on this supposition, more vegetable matter must be formed than many hundred thousand crops of the finest wheat on the most fertile soil.

Thus nature provides materials for the formation of moss; materials sufficient in quantity; materials, too, which do not speedily decay; materials which are not soon diminished in bulk; and materials which must of necessity have existed wherever any forest falls into ruins.

1. That the quantity of materials is sufficient will appear even from Dr Anderson's concession: for if a forest, when it falls into ruins, may yield sufficient matter for three feet of moss, we may safely allow that it would furnish three feet more, during the period of its growth, by its leaves and twigs, &c.; and if we suppose two or three generations to have succeeded each other, the account must be doubled or tripled.

2. That these materials do not (as the Doctor supposes every vegetable does) rapidly tend to decay, can be clearly proved. Leaves have been found 30, 40, nay 50 feet deep in moss, which had not undergone the smallest disorganization. Barks have been found equally entire. Birch bark of all substances seems to be least liable to decay; it is almost incorruptible. Pliny mentions, that the volumes that were buried along with Nerva were wrote on this: that though they had lain in the grave 400 years, they were perfectly entire. And Joseph Correa mentions, that the bark found in Lincoln fens, though it had probably lain five times that period, was perfectly fresh, especially that of the branches: that the silvery skin, or outer membrane, is discernible.

Even when exposed to the air, as well as buried deep in the earth, it is not liable to rapid decay.

Maupertius says, that among the numerous trees which lay on the ground in Lapland, destroyed through age, or blown down by the winds, many birch trees appeared whole, owing to the undecayed

state of the bark; but they crumbled into powder when trod upon: That the Swedes take the hint from this, and cover their houses with this *unperishable bark.*

Nay, even after the wood is not only decayed, but mineralized, the bark of trees has been found entire in an organized state. Mr Took mentions instances of this in Russian Lapland. In the martial springs of Ussona, &c. are discovered vast quantities of stems, branches, twigs, and leaves of birch trees, mineralized by iron; the texture of the wood is still visible; the tender white rind is preserved entire in its natural appearance.

In the copper mines of the Riphean mountains, similar instances are mentioned by Abbe Chappe. In these, and likewise in the Souxson mines, he says that pieces of wood are often found mineralized by copper; the internal part is almost reduced to charcoal; the copper is sometimes chrystallized in cells; the *bark* is still distinguishable; it is about four lines in thickness.

3. That these materials are not soon diminished in bulk, so as not to occupy one hundredth part of the space they did, as the Doctor supposes, is clear to demonstration. The leaves, and bark, and cones, and nuts, &c. of the trees found in moss, occupy nearly the same space as when they dropped from the parent tree.

Of this no proof is necessary: every one who has paid the least attention to the subject must be convinced of it.

The conclusion of the whole is, that the ruined forests of the north of Europe have laid the *foundation* of many of our mosses; I say only the *foundation;* on that foundation nature builds her work.

To point out the materials and progress of that work, by means of aquatic plants, &c. shall be the subject of my Second Essay.

The subject is difficult and intricate, but it is interesting and important;—it far exceeds my feeble powers. The short line of the human intellect never can fathom the depths of Infinite Wisdom displayed in his works; yet every physical fact we discover, throws a ray of light on the darkest and deepest subject, and elevates the soul with pure and solid satisfaction.

ESSAY II.

ON AQUATIC PLANTS.

AN

ESSAY

ON THOSE

AQUATIC PLANTS

WHICH

PROMOTE THE FORMATION AND RENOVATION

OF

MOSS.

TO ascertain the *Aquatic Plants*, which have contributed to the original formation of moss, is the object of this essay. This is, doubtless, a very difficult task; to some, it may appear a hopeless effort. It is utterly impossible to fix the precise period at which any one moss commenced its first growth; of course, it may appear equally impossible to ascertain what particular plants laid the foundation, or furnished the materials of it. It is even impossible to point out any moss which may be said to be so recent in its origin that we can mark the progress of its growth, even in the primary stages of it. There are few, if any mosses, that have not already survived generations of the human race: It may, therefore, appear impossible to ascertain what plants have contributed to its subsequent increase, as well as its original formation; for,

if we fix our attention to any moss, we must take it as it now exists. In this case, we may, perhaps, discover what are the plants that now contribute to its increase; but it does not follow that the same plants contributed to its original formation, or subsequent growth, in every period of it.

Direct information on the subject cannot be expected; and I do not pledge myself to furnish it. Yet the task is not hopeless, nor do I think it by any means impossible, to ascertain what are the plants which first laid the foundation of moss, and furnished materials for its subsequent increase:

For, if moss be renovated when dug; if we can by any means ascertain what is requisite for this purpose; especially, if we can point out the period of time necessary; and, above all, the precise plants which have furnished the materials for this renovation; it is not an unfair or unphilosophical conclusion, that the same plants may have contributed to its original formation.

More especially, if it can be proved that the same aquatic plants still flourish in lakes and marshy grounds; that some lakes and marshes have by these been converted into mosses within the memory of man, or since a precise period: Above all, if it can be shewn that these very plants can be traced in moss, through all its depth, the above conclusion must, in that case, be corroborated; and we may thus form a distinct idea of the aquatic plants that have given origin to moss; of the period requisite for its formation;

and account for all the various appearances it assumes.

With this view I shall, in this essay, shew,

I. That many mosses, when dug, are renovated; and then point out,

II. What is requisite to this renovation. I shall,

III. State some facts to ascertain the time required for this purpose:

IV. Point out the aquatic plants which furnish the materials:

V. Shew that the same aquatic plants still flourish in lakes and marshes:

VI. Prove that many lakes and marshes have been converted into mosses by the growth and decay of these plants:

VII. That these plants may be traced still in an organised state in moss, through all its depth. I shall then endeavour,

VIII. To ascertain the distinguishing qualities of these plants.

IX. I shall attempt, on this hypothesis, to account for the various appearances moss assumes; for the vast depth to which it sometimes reaches; and the different situations in which it is found.

Lastly, I shall state some general conclusions.

The above is the plan of this essay. I allow that it is a circuitous way of ascertaining the point at issue; it appears to me, however, to be the only certain method, therefore I have adopted it.

SECTION I.

That Moss, when dug, is Renovated.

This is a point of the greatest importance: I shall, therefore, endeavour to establish it upon the testimony of those who have had the most extensive means of information.

Some ingenious men have denied that moss is ever renovated when dug. Lentilius and Commelinus are decidedly of this opinion. Girard, in his account of the valley of the Somme, also denies that there is any renovation of moss in that district: He says, that the pits dug on the banks of that river are converted into lakes; that they are not again filled up with moss.

General de Jean is of a different opinion: He says that, upon examination, he found that these pits in that district are filled with aquatic plants, which, in course of time, are converted into moss.

Ribaucourt is decidedly of the same opinion: He says, that, in favourable circumstances, new moss is formed, and fills up the place of the old which has been dug.

Mr Headrick, in his account of Swinridge moor, says, that the old peat pits there are filled up to the

surface with new formed moss; but that this is more soft and spongy than the old.

The Earl of Cromarty in his paper, to which I have already referred, plainly asserts, that moss is renewed after being dug. His words are,

" In wasted moss pits, where water hinders to " cut the earth to the bottom, these pits are filled " again, in a good number of years, with new spongy " earth, which, in progress of time, will come to " the consistency of peat moss as at first; and a " scurfy heath turf will grow on the top of it." This is not a mere conjecture of that Noble Earl; his assertion is founded on experience; he says he was an eye-witness of the fact.

Dr King, in his account of the Irish bogs, asserts the same thing. He says, " that the turf holes, " and little gutters dug in them, are again filled " with new formed moss."

Degner describes the Dutch mosses with minuteness: he gives it as his decided opinion, that they are often renovated when dug. He says that the pits and ditches are filled with aquatic plants; that these are converted into turf: that this new formed turf, though not so solid, compact, or heavy as the old, is equally inflammable, and, if allowed to ripen, that they are equal to the best. He adds, that this is not a mere conjecture; that he has seen it, especially in the neighbourhood of Craneburg. He says, that the mosses in that district are intersected with many ditches to drain them. In these ditches a vast

quantity of aquatic plants speedily rush up; these are converted into moss: the turf dug out of them is soft and spongy, but inflammable. When dried, these turf are sold to sailors; by them they are used for stopping leakes in their vessels.

As Mons. De Luc has had more opportunities of surveying the mosses of Europe than most men, I used the freedom to write him in January 1806. I requested information upon this and many other points. To this letter I received an immediate reply: With the greatest frankness he furnished me with ample information. I wrote him again, requesting his permission to publish his letters: to this request he readily yielded.

I shall avail myself of this advantage; but I rejoice to add, that *though this venerable philosopher be entered into his 80th year, he is preparing for the press an extensive and important work upon the subject of geology, from which I expect more ample information.*

In his first letter he says, he never saw more "peat moors than in summer 1804, when travel-"ling through Brandebourg, Mecklenbourg, Hol-"stein, and Shleswig, or with more peculiar circum-"stances." He says, "that three distinct kinds "of peat grounds may distinguished." His words are:

"The first of these kinds is very common over "all the north parts of the Continent of Europe. "The peat lies on horizontal parts of sandy hills,

" a little lower than the general surface; these levels " are covered with heath; the peat is commonly very " shallow; the surface is very rough, giving me an " idea of those lands in Ireland, where are bog-trot- " ters; it rises like mole-hills; the intervals between " these are a boggy soil of soft peat. I think, how- " ever, that the peat would thicken on these soils, " were it not the source of fuel for the inhabitants, " and constantly disturbed.

" This kind of peat grounds cannot answer my " main purpose, that of finding natural chronome- " ters, as they are constantly acted upon by men; " but if long and attentively studied by natural phi- " losophers upon the spot, they would be useful in " determining the cause of peatification (if I may be " allowed to coin that word.) This shallow peat is " a sort of incrustation on the sand. When the for- " mer is removed the latter is laid open; but *in time* " *this sand is again covered with peat.* If the pro- " gress of its renovation were studied, and experi- " ments made, these might tend to ascertain the " causes of this renovation."

" If this kind of peat ground lie on a much lower " level than the surrounding hills, it is sometimes " covered with thickets of trees; such as the *alnus*, " which is fond of moisture. These levels are im- " passable in wet weather; the peat is as soft as mud " between the stems, or rather pedestals of the trees: " It is not very deep, so that in summer, when plants " grow over it, one may go in to cut the wood."

The second kind of peat grounds he thus describes: "They lie on a lower level, not much above the "rivers, and are traversed by rivulets. I have "seen a vast extent of these in Brandebourg and "Brunswic. *When peat is dug from these, it is "renovated and grows up again.* These grounds "form horizontal meadows, on a sandy base; some "parts of them afford pasture in summer; in winter "they are too deep under water for this purpose: "other parts, not so deeply overflowed, with some "dressing, become good hay fields, and yield excel-"lent pasture in autumn.

"A third kind of peat ground particularly attract-"ed my attention in the survey of these countries. It "is connected with lakes, which appear innumerable "among the sandy hills, and of all sizes: these "form commonly a part of all the dales." The manner and rapidity with which moss is renovated and formed in these mosses, and by which these lakes are filled up, I shall state afterwards.

Suffice it to say, that, from a very careful and very extensive survey of all these kinds of peat grounds, he gives it as his decided opinion, that there is, in *all* of them, a renovation of the moss when dug.

From the above testimonies it appears certain, that moss grows up again, and is renovated in favourable circumstances. Every attentive observer must have seen instances of this, especially in low level *kct-moss*, as it is called, in this country; and

I cannot but solicit the attention of the public to this point. In order to assist their researches, I beg leave to mention a few circumstances, which will enable them to ascertain the fact.

1. The new formed moss in these old pits can easily be distinguished. It is always more soft, spongy, and porous than the old. The organization of the plants is obvious in the former; in the latter the organization is almost entirely gone, especially in the lower strata.

2. The new formed moss never adheres to the old. Picard takes particular notice of this: He says, "That when new moss is formed in the pits, it never "adheres to the old; that it can thus be easily dis- "tinguished, even at the greatest depth."

Mr Headrick makes a similar remark of Swinridge moor: He says, that the sides of the pit are still perpendicular and entire; that the old and new moss seem never to have coalesced. And he farther observes, that this new formed moss could not be occasioned by any earth or dust or moss blown into these pits; that it must be owing to the growth of the moss; for the surrounding surface is all covered with heath and herbage.

3. The marks of the spade may be seen in the old pits. Degner takes notice of this circumstance: He says, "that he was informed by workmen of credit, "that this is often the case at the depth of six and "seven feet in these pits:" He adds, "that they "shewed these marks to himself. That this was a

" clear proof, that moss had been dug by former " generations, on that very spot; and that the moss " they were then digging, was new formed since that " period."

4. Upon examining these pits, too, other circumstances may lead to this conclusion; sometimes utensils, &c. are found in them, which clearly ascertain the fact. I have in my eye an instance of this which occurred in the parish of Denny: four feet below the surface of a moss, the marks of an old pit were discovered; in the bottom of it some sheaves of flax were found; this flax was still entire, though brittle; when exposed to the air, it, however, speedily crumbled down.

It appears to me unquestionable, that this pit had been used for watering the flax; and it seems equally certain, that the four feet of moss above these sheaves had been new formed after that period.

I need not say, that utensils found in such circumstances are evidences of the same.

No doubt can be entertained upon this point; moss is certainly renovated in favourable circumstances; but, as Degner observes, this renovation is not always observed; and he assigns the following reasons of this: That in Holland, the ground from whence the turf is dug, is frequently cultivated; that moss is so valuable as a fuel, that it is greedily dug without allowing time for its renovation; that in some situations this renovation is slow in its progress, though in others very rapid: I may add to this, that it appears cer-

tain, that in some cases, too, there is no renovation at all.

There are certain requisites, without which it cannot take place, or may be greatly retarded *.

To point out these shall now be my object.

SECTION II.

What is requisite to the Renovation of Moss.

It appears, from undoubted evidence, that when the pits dug in moss are drained of water, and left dry, or when these pits are large or very deep, or when a current of water is permitted to pass through them, in all of these cases, there is little or no renovation of moss; that in order to expedite this process, it is requisite that the pits be left full of water; that

* It is generally allowed, that coal is likewise renovated when dug. Buffon in his Mineralogy, says, that he has seen this new formed coal. Mr Gennett says, that in the Liege mines this is the case: a bitumen impregnated with carbon, is said to transcide the veins which forms coal; and in 40 years these mines are filled up with this.

these pits be small, and not very deep; and, that the water in them be stagnant.

1. In the *first place*, It is requisite that the pits be left full of water :. Dr Anderson himself, though he seems to doubt of the renovation of moss at all, and though he never saw an instance of it in Aberdeenshire, in the experience of 30 years, acknowledges, that this is the general opinion of the inhabitants of that county. His words are, " I acknowledge, that " where the Aberdeenshire mosses are wrought in a " foret, *i. e.* where the moss left is laid dry, they are " never supposed to grow; it is only when they are " pitted." This remark is founded on experience.

The Earl of Cromarty makes the same distinction: His words are pointed; " I have observed, that when " they dig the peats to the channel, or in places " where the waters run off and do not stagnate, the " mosses did not grow nor revive there again. This " moved me to order my tenants not to cut the moss " to the channel, nor in very large openings, but in " small pits, that they might grow more hastily." He adds, " The event answered my expectation." How plausible is his Lordship's account of the matter? How like the language of unadorned truth? How consistent with the experience of every candid, careful observer; and the general opinion of those who have examined the subject with precision?

I may add, that it is equally consistent with analogy; for if moss be renovated by the growth of

aquatic plants, as I shall endeavour to prove, it is impossible that this renovation can take place when the pits are left dry, and no aquatics can grow.

2. *Secondly*, His Lordship takes notice, that in small pits this process is more rapid than in very large openings. This remark tallies with the testimony of every other writer upon the subject.

Mr De Luc states this distinction from the experience of Mr Findorf: his authority is high; his opportunities of information were extensive; he was Commissary-General of Duvels moor for many years; and a curious enquirer into the natural history of peat moss. He says, that small pits are prefered to large ones; and he assigns the reasons of this: "They "prefer small pits, not so much for the sake of re-"novating the moss carried off; this is an object of "no importance to them, as it abounds so much in "these regions, it is more for the sake of their cattle; "for when the pits are small, they are *soon* filled "up, whereas large pits would require an age for "this purpose."

Degner makes a similar remark of the Dutch mosses: He says, that when a large pit is dug, and a large sheet of water is left exposed to the agitation of the winds, the vegetation of aquatic plants is retarded, of course, the renovation of the moss is checked; whereas, in small pits aquatics rush up with rapidity, and the renovation of the moss is proportionally rapid.

Poiret makes a similar remark; and he assigns a similar reason for it.

It may not be improper to add, that I have examined many mosses in this neighbourhood: the inhabitants all agree in affirming, that the moss pits of the above description are filled again with peat; and many assert, that they have dug new peat out of these old pits.

3. *Thirdly*, When these pits or pools are very deep, the renovation of moss is less rapid. In order to expedite the process, it is requisite that they be shallow. Poiret assigns the following reasons for this: That a greater variety of aquatic plants grow in shallow than in deep waters; in the latter, only those can flourish which float on the water, and require no soil to fix upon; in the former, both those which float on the water, and those which fix in the firm soil of the bottom, spring up and flourish, and thus promote the renovation of moss with more rapidity.

4. *Fourthly*, It is requisite that the waters in these pits be stagnant. If, on the contrary, there be a current in them, aquatic plants grow with less rapidity, or, though they grow, they are not converted into moss. They grow with less rapidity; for the seeds of these plants are floated down the stream: They do not, therefore, fix so readily, nor flourish so well, as in stagnant water. They are not converted into moss; for, as I shall shew hereafter, the current robs the water of those very qualities that are requi-

site to the formation of moss from aquatic or ligneous plants.

General de Jean observes, that, in stagnant pools, the progress of the formation of moss is perceptible to the eye: "That in some there is only a kind of "net-work begun on the verge; that others are half "covered over with it; while some are wholly fill- "ed, to the depth of two or three feet; that, after "a certain progress, these plants reach the solid base "at the bottom of the lake; that other plants rise "upon the surface; that these, by being exposed "to the influence of the sun and air, are dissolved "and reduced to common mold, forming a slight "soil over the moss; that this soil yearly increases "till the aquatic plants disappear; that meadow "grasses rise up and occupy their place; that these "meadows are at last consolidated; and, that the "plough can thus pass over this solid soil, where, "thirty years before, sheep could not pasture. This "progress, he says, is so obvious, that it cannot be "doubted."

He adds, that, under the soil, moss is still forming; and, he says, that the STILLNESS of the waters in these lakes, and the equable temperature, is peculiarly favourable to the growth of aquatic plants, as the calmness and equable temperature of the sea in polar regions is favourable for fishes.

Accordingly, Poiret observes, that when all the above circumstances combine, that is, when the pits are not drained of water, or too extensive in their

surface, or too deep, and especially where there is no current, that, in such favourable circumstances, the formation and renovation of moss is very rapid ; that fish-ponds would soon be filled up by it, and canals would soon cease to be navigable ; that they would all speedily be converted into mosses. He adds, that the Dutch are completely aware of this, but that their indefatigable industry in using every precaution prevents it. With this view, they either endeavour to give an occasional current to their canals, by the influx of the adjacent rivers, when they are swelled above the level of the sea at low tides, or carefully clear these canals of moss. He says, that without these precautions, compact moss would soon occupy their place.

From the above statement, it would appear, that there is no room for disputation upon this subject. One may assert that moss is renovated ; another may deny it: Each may be right or wrong, according to the particular spots he had examined.

All depends upon circumstances: In some situations, moss may be, and certainly is renovated with great rapidity ; in others this renovation cannot take place, or it may be so slow as not to be perceptible in an age.

Hitherto we have only endeavoured to ascertain the fact, that moss is renovated, and to shew what are the circumstances requisite to expedite this process.

It would be very satisfactory if we could form any conjecture as to the rapidity with which this process

is carried on, and the time requisite to accomplish it. I say, conjecture, for it is the utmost we can expect on this subject. Yet there are a variety of facts that render it probable that it does not require a long period.

These I shall state, in

SECTION III.

Time requisite for the Renovation of Moss.

Third place, Degner says, he was informed by the old inhabitants of credit, that ditches not too wide nor deep were filled anew with excellent turf, in 70, 80, or 100 years; but that this operation was much more rapid in a slimy than in a sandy soil.

He mentions, too, that it is a well known fact that a ditch 10 feet wide by 7 feet deep, is often so filled with aquatic plants, in 10, 20, or 30 years, that men and cattle may safely pass over it. He says, that though the bottom be loose and liquid, it is solid on the surface, and that in an age or two the whole would be ripened into turf.

Mr de Luc has been at great pains to ascertain the period requisite to the renovation of moss. He has stated a variety of facts with this view. He mentions, " That Mr Findorf assured him, that the pits " dug in Duvel's moor were in a few years filled up " with aquatic plants: That, in *thirty years* these " were converted into a firm, spongy substance. " That the solid surface of this, at the end of that " period, nourishes heath and other ligneous plants " that grow on the adjacent moor."

His observations were founded upon experience, and the accuracy of them is thus attested by De Luc, in the following words:

" *I saw* these pits in all their different stages: being " booted, I sounded some of them with a pole to " know *their age*; I then boldly stepped into the " floating bed, which *sunk under* me; by this means " I was half leg under water. The surface sunk and " rose according to the pressure; but with my pole " I easily felt the bottom, while the surface support- " ed me from sinking.

" Mr Findorf shewed me other pits where this " matted substance had reached the bottom; and " others so compact *that I walked* on them with as " much ease and safety as on the rest of the moor.

He further adds, " That the surface of these pits is " covered with all kinds of ligneous and aquatic " plants, that delight in such a soil; that these alter- " nately overtop one another; that the ligneous " plants make the greatest progress in a DRY SUM-

" MER, so that the surface seems to be *entirely* co-
" vered with THEM: That the reverse is the case in
" a RAINY SUMMER: That the aquatic plants over-
" top the ligneous and choke them, insomuch, that
" the whole surface seems to be entirely covered with
" a matting of aquatics, which, by decaying, form a
" soil for the ensuing season: That, if it continue
" rainy for a succession of years, these aquatic plants
" continue to prevail till a dry season ensue."

He adds, "This is so certain, that in the succes-
" sion of beds, or strata of the moss, these different
" species of plants are distinguishable. These strata
" are either composed of the roots and fibres of lig-
" neous plants, or of the remains of aquatic; so that,
" upon examining some of the cuts of the deepest
" canals, he saw *distinctly* the produce of the several
" years." He says "he could even distinguish by
" this means, the different produce of a *wet* and *dry*
" *season*, from the residuum each had left, as well as
" the gradual formation of moss, in all its progress,
" from the white, soft, and spongy, to the brown,
" hard, and black."

The general conclusion he draws seems to me natural and well founded. It is, indeed, contrary to the general AXIOM which Dr Anderson lays down, viz. that the produce of moss is small, and its progress in forming very slow. "The formation of " peat moss," says De Luc, "*is thus obvious.* " *The rapidity of its increase and renovation is* " *equally so.*" With his usual accuracy he adds;

"one inch at the base is perhaps equal to the ma-
"terials of two feet at the surface; yet, even
"upon this allowance, the growth of moss, thirty
"feet deep, does not lead us back to *a remote*
"*æra.*"

I was so much struck with the above account, that I wrote the author of it again in January 1806. I requested him to furnish me with any farther information he could on this subject; and, if possible, to fix some *data* by which I could ascertain more accurately the period requisite to the renovation of moss. To this he gave an immediate reply; and in this his second letter he states the following particulars on this point in these words: "You ask me what time
"is requisite for the renovation of peat in the second
"kind of mosses I have described in my former let-
"ter? I cannot answer that question with certain-
"ty; but as I know such a ground near Brunswic,
"and as I am soon to write to a friend of mine there,
"I will beg of him to procure every information on
"this point, and communicate it to you.

"Yet I know that when peat is dug out of small
"pits, these are soon filled with good peat. There
"the conferva, the very first summer, fills the water
"with its green clouds; the sphagna thicken the
"bed it forms; and the growth of other aquatic
"plants is very rapid; so that, in the course of 30
"years, good peat may be again cut out of the same
"pits." He adds,

"The way in which I have seen peat cut in the "second kind of moss I have described in Brande-"bourg and Brunswic is this: A long ditch is cut "down to the sand, four, five, or six feet deep, in "the direction of the course of the water to some "rivulet. There the section of the whole moss is "seen on the side where this operation goes on. "They begin by cutting the turf on the surface to "a certain breadth, throwing it to the opposite side "of the ditch. Then about three or four feet of "good peat is cut, in the usual form of bricks, and "piled up to dry:—this is the work of summer. In "autumn this ditch begins to fill up with water, and "the peat is too soft to be cut. The next summer "another such slip is cut in the same manner, and "this process goes on yearly on the same side of the "moss. Meanwhile the peat grows again; so that, "at a certain distance of time, these pits are repaired "to their original level. There are many such "trenches in meadows of great extent which belong "to different parishes. These trenches are at that "distance from each other, that when the cutting is "arrived at the limit on one side, the work may be "begun again on the new formed moss on the other, "in the same manner as the regular cutting of trees "is carried on in a forest."

It has been stated already, that in some situations the renovation of moss is more rapid than in others. In the vicinity of Craneberg, this process seems to be uncommonly rapid. Degner, as I have shewn,

states that the mosses there are intersected with many ditches on purpose to drain them. In these a vast variety of aquatic mosses rush up; and though these ditches are cleared, in a few *weeks* they are filled again; so that they require to be cleared *often every summer*. This, he says, is not so requisite in winter. Yet if the weather be mild it is necessary, as they grow even then; and unless thus cleared, they are consolidated into turf.

I only add, that the Earl of Cromarty states, that some mosses grow up in a shorter time than others. This assertion is founded on his own experience; he was an eye witness of the fact. His words are:

"I have observed that pits which have been dug
"since I *remember*, have grown up again with new
"peats; and that, too, sometimes *oftener than once*
"in the same pits."

That peat moss is renovated to a considerable depth seems therefore unquestionable: that this process does not require a long period, but is sometimes accomplished in an age or less, seems equally probable: that it has taken place in many moss pits in this parish, I am fully convinced:—But my attestation is utterly superfluous, after stating such a variety of well-attested facts.

It would, however, be highly satisfactory, and tend greatly to the elucidation of this subject, if we could ascertain precisely the species of aquatic plants which tend to expedite this process.

This is the subject of

SECTION IV.

Mons. De Luc has paid particular attention to this subject: he gives the following account of it, founded on the experience of Mr Findorf. In speaking of the renovation of the mosses of Bremen, he says, that

" It is customary to dig pits in these mosses. " These are about twenty feet long by six feet wide. " This shape and size is preferred, in order that they " may be able to throw out the water with a bucket " when they cut the pit. When these pits are form- " ed they are left, and allowed to fill up with water."

The manner in which moss is formed again in these pits, he thus describes:

" The *first* year they are filled with a mucous sub- " stance that swims on the water like a green cloud.

" The *second* year this substance is composed of " *fine threads*, knit together, and garnished with " very small leaves, and flowers, and seeds; so that " the water is filled with these nearly *two feet* deep."

" The *third* year this is covered with *(mousse a " long panaches)* mosses with creeping roots and

"leaves and branches. These cover the water en-
"tirely, arrest the dust, and all the seeds which float
"in the air. Thus it becomes a fit soil for aquatic
"plants, as rushes, reeds, grasses, &c. &c. which
"grow with great luxuriance.

"The fourth year these plants are so high and
"thick set, that they change the surface on which
"they grew, and sink with it in the water; yet the
"mosses reach again, and cover the surface, receive
"new seeds, and produce a new race of aquatic
"plants. These sink the surface or sward lower
"and lower, which, being always garnished anew
"with mosses within and without, at last reach the
"bottom of the water in a few years. The plants
"at the bottom then decay and die; compressed by
"the incumbent weight, they become somewhat con-
"solidated. Those on the surface also decay and
"drop in their turn. Descending by little and little,
"they at last occupy the place of the water, and fill
"up the whole pit; so that, in 30 years, its surface
"is so solid as to nourish heath and other ligneous
"plants that grow on the adjacent moor."

From the above account, we may learn, what are the precise plants which promote the renovation of moss. The mucous matter which appears the first year like a green cloud, no doubt consists chiefly of the conferva: To ascertain this, I applied to Mr De Luc himself. In his second letter, already alluded to, he says, that

"The green cloudy matter, I mentioned, is cer-
"tainly the conferva, a vegetable, the fructification of
"which has been discovered by microscopic observa-
"tions of one of my countrymen."

The growth of the second year may also be ascertained; the fine threads that knit together the mass, is most probably a collection of those aquatics whose roots and leaves are of a capillary form; such as the byssus or chara, vulgarly called horse-tail, equisetum, &c. The small leaves and flowers and seeds which cover the surface, are most probably the lemna or duck-weed. This certainly grows on the surface of water, in ponds, and frequently covers it all over; its roots are of a capillary form; and it is very rapid in its growth *.

The mousse a long panaches which he describes is no doubt the sphagnum. This Mr De Luc asserts, in his second letter to me, in these words:

* The lemna is very frequently found in the moss pits in this neighbourhood. I examined one which had been dug only a few months before; the surface of the water was nearly covered with the beautiful verdure of the small green leaves of this plant. Upon stirring the pond, I found that the roots reached upwards of six inches deep; all that space was, of course, filled with the fine delicate net-work, which the capillary roots of the plant had formed. I plucked up a part of these plants; I have kept them in water ever since, in a small glass bottle; they have flourished amazingly, and grown with rapidity; the whole water is now filled with them; and the interstices between the roots, are filled almost entirely with the conferva.

" The conferva begins to be the bed of the sphagna, " and thus contributes much to the preparation of " the mass of vegetables, which are turned into peat. " It fills the water with its green clouds the first sum- " mer; the sphagna thicken the bed; the growth of " other aquatic plants is very rapid."

From the above facts, it would appear, that the following aquatic plants furnish the materials for the renovation of moss in these pits:

The conferva, lemna, byssus, &c.

The sphagna, and other mosses.

The varieties of aquatic grasses, rushes, and reeds, &c.

Having endeavoured to establish the fact, that moss is renovated when dug, and to ascertain and point out a few of the aquatic plants which furnish the materials, I now proceed to shew,

SECTION V.

In the fifth place, *That the same species of plants have contributed, and still contribute to the original formation of many mosses:* this conclusion is natural and obvious.

On this important subject, I cannot but communicate the information I obtained from Mr De Luc, in his letter January 1806: He points out the plants that contribute to the formation of moss, and the process by which that is accomplished, in the following manner:

" *A third* kind of peat ground has attracted my " attention in the survey I took of Brandebourg, " Brunswic, and Shleswig: It is connected with " lakes.

" The bottom of every dale is a meadow, on a sub- " soil of peat; this, by gradually advancing into, con- " tracts the original extent of the lakes; and, it is " well known in that country, that many large lakes " have been converted into smaller ones, by the peat " advancing from the original shores, and many " places now meadows, and only traversed by a " stream, had still a lake in the middle of them, in " the memory of old people."

The manner and means by which this change is effected, he minutely describes in the following words:

" I have said that the peat gradually extends for- " ward in these lakes, contracting their surface. This " is occasioned by the following causes. The sandy " sediment carried into these lakes by streams, gra- " dually raises the bottom of them: The consequence " of this shallowness is the growth of common reeds; " these are like the van in the progress; these ad- " vance forward as the bottom of the lake is raised. " No peat appears among the reeds, nor even among

" the small aquatic plants which form a zone behind
" them.

" 2. Behind the zone of reeds, another rises up: " It is distinct from the former; and it is composed " of different aquatic plants, which rise much less " above the surface of the water.

" This zone, which has a greater breadth in pro- " portion as the declivity of the bottom is small, " is not so thick as to prevent small boats passing " through it. These bend the plants in the water, " which is still clear; and these plants form, like the " twigs of basket-work, for the future peat. They " differ in their aggregates in different lakes, when " distant from each other. To enumerate the parti- " cular species of which they consist is difficult; I " shall only specify those which are found in the " lakes round Rostock, as delineated to me by Pro- " fessor Linek, of the University of Mecklenburgh " Strelitz; they are as follows: scirpus maritimus, " scirpus cæspitosus, scirpus paucifloris, equisetum " palustre, equisetum fluviatile, eriophorum polysta- " chion, eriophorum vaginatum; the last of which " retains its form and appearance longest in the re- " mote peat *.

* This plant exhibits a very singular appearance in some mosses in this neighbourhood. It may be traced, in an organized state, to the depth of four feet. The roots and stems of it form a mass so hard, tough, and tenacious, that few edge-tools can pierce it. The interstices of the moss, which are formed of other plants, are soft and porous. When peat is cut out of

" 3. Behind this zone, the conferva begins to embrace those plants with its green clouds; this forms the bed in which the different species of aquatic sphagna grow; these thicken the matting, and favour the growth of common moss plants, on the more compact surface; there the little boats are stopped; the lake is no farther navigable; but the surface is still yielding, and will not support any great weight.

" 4. Behind this, another zone appears; it consists of the same kind of plants; but these are so interwoven, that the surface is more compact and bears more weight, though very elastic. On this zone some grasses appear. I have sometimes been drawn unexpectedly on this zone: At one time, being inattentive to the direction I had followed, I missed my way in retiring; by this means I was obliged to walk there a long time, half leg up, in water, before I could find a more solid ground: The surface that supported me was like a mattress; the water that rose was still clear.

" 5. Proceeding backward from this zone, the surface becomes more and more compact; many kinds of land plants begin to grow over it, especially where that surface, by being raised, is dry in summer. There the tedum palustre, vaccinium occycoccon, comerum palustre, erica tetralix, and va-

these, it can be easily torn asunder; that which is composed of the eriophorum, on the contrary, can scarcely be separated.

" rious kinds of grasses grow. Thus begins a zone " on which cattle may pasture in summer. There, " also, peat is formed, as may be seen by the colour " of the water; tinged into dark brown, it assumes " the colour of moss water.

" 6. From the beginning of this useful zone, still " backward, the ground becomes more and more " solid; hay may be made on it in summer, and it " yields a good pasture in autumn: Yet, even in " these grounds, there are dangerous places, on ac- " count of the small streams that pervade them.

" These can only be discerned by the different ap- " pearances of the grass that grows in them, known " only to the people of that country. There are fre- " quented paths which must be carefully kept. In " the line of these, plants are laid over these hidden " streams, which serve the purpose of bridges. In " going across these grounds at random, one may " sink suddenly very deep in peat-mud there accu- " mulated.

" This happened once to me, quite unawares; " luckily I could throw myself back on a more solid " path, and thus crawling out, I was quit for being " covered with peat-mud.

" This is the last zone that can be distinguished by " a decided difference in the progress.

" I have said before, that the succession of these " different zones, from the border of the water " towards the original border of sand, represents the " succession of changes that have taken place through

"time in each of the anterior zones, so that, in pro-
"portion as the reeds advance, new zones are form-
"ing behind the advancing reeds, on the same places
"which they thus abandon. That process is more
"rapid in lakes which are originally shallower, and
"slower in deep lakes. It seems even to be stopped
"in some parts where the reeds, which cannot ad-
"vance beyond a certain depth, approach the brow
"of a great declivity under water; there, the pro-
"gress, if continued, is not perceptible: But in
"lakes originally not very deep, and in which the
"sandy sediments are advancing all around, the reeds,
"forming a ring, gradually contracting its circum-
"ference, meet in the centre; and at last these reeds
"themselves vanish, so that, instead of a lake, a mea-
"dow occupies its place. In some of these meadows
"attempts have been made, either for ornament or
"use, to keep up a piece of water; but the attempt
"is vain, excepting at a great expence: for luxuri-
"ant aquatic plants soon occupy that space, and the
"peat, advancing rapidly, restores the meadow.

"Such is the process observed in almost all the
"dales, in *an immense extent of country*, by which
"*lakes and pools* are converted into meadows and
"mosses."

Mons. Poiret gives a similar account of the formation of moss from aquatic plants; he likewise specifies what kinds of plants contribute to this.

He says, that mosses are formed either

"*First*, In morasses, that is, in planes where the

"waters are shallow; in these, marshy plants abound." He enumerates some of them: "Grasses, mosses, "rushes, the scirpus, the (preles) horse-tail." Or,

"*Secondly*, In canals and deep lakes, where only "aquatic plants prevail." Among these he mentions the conferva, lemna, byssus, and potamogeton.

So that both he and De Luc agree, that the same plants which occasion the renovation of moss in pits, promote the growth of it in marshes and lakes.

Mr Poiret's account of the manner in which moss is originally formed, claims particular attention; more especially as he points out the plants which contribute to the formation of it.

I have already shewn that it is requisite to the renovation of moss, in the pits dug in it, that the waters be stagnant. Poiret observes the same thing when moss is formed in lakes or pools. He says, "That "if there be a current in these, or if they be much "agitated by the winds, as in great lakes, the growth "of aquatic plants is retarded; but when the waters "are stagnant and tranquil, and not very extensive "in their surface, that they are speedily stocked with "aquatics."

These he distinguishes into two general orders:

"First, those that float upon the waters, and re-"quire no soil to fix upon; Secondly, those which "fix upon the bottom of the lake."

Of the first order he names the conferva, lemna, byssus, &c. "These," he says, "are the first that "make their appearance. By annual increase they

" form a soft green crust over the water: this is " smooth, and seemingly solid till trod upon. This " first layer of vegetables floating on the surface sinks " to the bottom: at last they form a soil fit for the

" Second order. The seeds of these floated along " the surface of the water, sink to the bottom, and " supply that soil with a stock of plants fit for it." Of this order he names the following numerous species, " the potamogeton, the chara, myriophyl- " lum, ceratophyllum, &c. which adorn the bottom " of such lakes.

" These rush up with astonishing rapidity, and in- " crease annually, till the bottom of the lake, when " the waters are clear, may be seen like a rich fer- " tile meadow.

" These two genera of plants," he adds, " contri- " bute to furnish abundant materials for the forma- " tion of moss, and they are the grand basis of this " substance in such situations.

" But, upon the ruins of these, other more beau- " tiful and majestic plants rise up and adorn the sur- " face; the butomus, with its rosy red, the sagit- " taria, with its milk-white flower, the nenufar ne- " lumbo, with their yellow and purple hue, recline " on the surface of the lake."

He observes, in general, " that the most part of " the above plants, whether they float on the surface " or sink to the bottom, are of a pulpy, tender, and " spongy texture; their fibres are neither hard nor " tenacious; their roots, for the most part, consist

" of capillary tubes; they have no coriaceous nor " ligneous structure, of course they are more speedi- " ly dissolved or decomposed than marshy plants to " be described afterwards: they are converted into " a pulpy, black, and heavy substance, which sinks " to the bottom of the lake."

He farther observes, " that there are particular " causes which tend to expedite or retard this de- " composition, and furnish less or more moss." Of this he gives the following instance.

Mr Van Marum, in his letter to Mr De Faujas, observes, " that the conferva was singularly favour- " able to the formation of moss: that he had an ex- " ample of this in a fish pond: that though he cut " and carried off the aquatic plants which incommod- " ed the fish, or concealed them from his view, yet, " in four years, four feet of moss was formed in this " pond.

" During eight years after he had cleared the pond " of this moss, no conferva appeared. The myri- " ophyllum flourished in great abundance, which he " frequently removed; yet, when he emptied the " pond after this period, he found no moss in it. " From this he concluded, that the conferva was the " principal cause of the formation of moss.

" It appears, too, that the frequent clearing of the " pond of the aquatic plants retarded the process of na- " ture in the production of moss. Van Marum also " observes, that the conferva, in harvest, becomes " specifically heavier than the water: that it sinks to

" the bottom, and carries along with it the other aqua-" tic plants: that thus their putrefaction is retarded, " and the process of the formation of moss is pro-" moted."

From the above account it appears obvious, that the same plants, in similar circumstances, tend to form moss in lakes, which promote the renovation of it in moss pits.

Poiret, however, observes, " that the moss formed " of the above aquatics is always soft and slimy: that " it is never fibrous, and ought to be distinguished " from that in which the fibrous form of the origi-" nal plant appears. The carbon it contains is like " a small powder, as it proceeds from herbaceous " plants. When it is the production of ligneous " plants, it is frequently found in the organized form " of the roots and branches of the original trees, " though these are often bituminated as in coal; but, " though loose and pulpy when lately formed, even the " moss produced from aquatics by pressure becomes " more compact and hard. It is sometimes pure; " more frequently it is mixed with mud, or small " particles of calcareous matter, or the shells of aqua-" tic animals."

It is almost unnecessary for me to add, that Mons. Rozier gives a similar account of the origin and formation of moss in lakes: He says, " that all the " genera of aquatic mosses, especially the ceratophyl-" lum and myriophyllum, as above described, con-" tribute their part; but he especially takes notice

" of the ranunculus aquatilis, and of the rapidity of " its growth :" He says, " that it frequently covers " a whole lake with its leaves and stems and flowers, " and gives it the appearance of an extensive mea- " dow : that he has plucked them three and four " fathoms long, reaching to the bottom of the lake : " that in winter the whole plant drops and sinks to " the bottom : that new shoots spring up next sum- " mer, nourished by the roots and decayed leaves of " the former : that, by this single plant, a deep lake " may soon be converted into moss."

It only remains, that we endeavour to ascertain what are the plants which contribute to the formation of moss in marshes or shallow waters.

Poiret observes, " that the mosses formed in such " situations are distinct from those formed in lakes " or deep waters, and that they exhibit a different " appearance. Composed chiefly of the roots, stems, " and branches, of marshy plants, they form a loose, " porous, and elastic substance, retaining the organi- " zation of the original plant : these he calls by the " general name of fibrous moss.

" The plants which chiefly compose this kind, he " says, are reeds, scirpus, carex, rushes, iris, mosses; " and especially the hypnum and sphagnum, &c. " These cannot flourish but in marshes ; they perish " as soon as the ground is drained ; their roots must " be nourished by a moist soil ; while their stems rise " up above the water.

" When these are reduced to fibrous moss, they " scarcely undergo any decomposition ; their roots

" and stems retain their form for ages: over these " new generations of the same plants rise up; the " soil is thus annually raised, till the whole marsh is " filled with this species of fibrous moss many feet " deep."

How these plants are preserved, and retain so long their organization, is a phenomenon which claims our attention: it will furnish the subject of another essay. It may be proper to observe, however, that all plants are not equally susceptible of being thus preserved: Poiret takes notice of the aquatics, " that they are " more speedily dissolved: that the grasses, on the " contrary, whose leaves are dry and coriaceous, are " almost entirely preserved: that the mosses, above " all, retain their organic form for the longest period."

He farther observes, " that fibrous moss is often " found covered so deeply with alluvial soil above it, " that its origin must be traced back to the remotest " ages: that it seems therefore impossible to say how " long they may retain their organic structure, when " thus secluded from the sun and air; yet it seems " probable, that they must progressively pass into the " state of solid moss, totally disorganized."

He adds, " that this fibrous moss, though loose, " light, and elastic, may be hardened to such a pitch " by compression as to receive a polish like wood: " that when thus compressed, it can only be dis-" tinguished from wood by the horizontal strata, in " which may still be seen the fragments of the stems " and leaves of grasses preserved entire."

SECTION VI.

Sixth place, It seems probable, if not certain, *that many lakes in the north of Europe have been converted into moss*, by the growth and decay of these, or similar aquatic plants. That this has been the case, is the opinion of those who have had the best opportunities of information on the subject. I need not remind the reader, that De Luc states this to be a well known fact in Brunswic and Brandebourg. Picard says, that, according to historians, all the mosses in Holland were formerly lakes; and Poiret thinks, that it is beyond a doubt, that the largest and deepest lakes may be converted into marshes and mosses, and then into meadows, by aquatic plants: that these, by being consolidated, may ultimately become a soil fit for all the purposes of agriculture: He says, that many of the mosses and meadows of France appear to have been formed in this manner.

He thinks the whole valley of the Somme is of this description. Girard is of the same opinion: He says, that the whole valley has been formerly an

extensive lake: that this lake, by being partly drained, has been converted into a moss or marsh, with a river in the middle of it. He accordingly thus describes it: He says, "that it is covered with two feet "of soil; below this, there is from six to ten feet of "moss, from Amiens to Pecquingy; opposite to "Etoile, it is even 30 feet deep. The lower part of "the city of Amiens is built upon a subsoil of moss, "12 feet deep in some places; below this is a stratum of marl; and below this marl, a bank of "sand and sea-shells: all this proves, that this moss, "however remote its origin may be, has been formed "since the sea receded from that spot."

Add to this, that the valley has risen considerably within a few ages: this is owing to the stagnation of the waters, which has occasioned an accumulation of aquatic and marshy plants, and, by that means, an accumulation of moss.

These waters, when the valley was low at first, behoved to be deep; they were then navigable lakes; accordingly, boats are found buried in these mosses in different places, and at different depths.

Poiret observes, that, at this early period, no fibrous moss would be formed, because marshy plants could not flourish in the deep waters. Aquatic plants would then abound; these have contributed to the formation of that ancient black compact moss, found in the lower strata.

But as the soil rose higher, the waters would, in proportion, become more shallow; marshy plants,

such as he described before, would supplant these aquatics: the wreck of these would at first form an intermediate kind of moss, partly fibrous, and partly compact.

At last the surface rising higher still, would become fit only for marshy plants; fibrous moss would therefore form the superior strata; there the roots and branches of marshy plants would form the component parts. This is precisely the case; and it shews that, at the formation of this buzin, or rushy reedy turf on the surface, the valley was only a marsh, though unquestionably a navigable lake at a former period.

Poiret adds, that it is true that fibrous peat is sometimes found in the bottom of very deep mosses; but he accounts for this phenomenon. He thinks, that, after the marshy plants had grown up, the water must have been stemmed, and formed a lake over what was formerly a morass; that this lake would, in time, be filled with aquatics, in the manner above described, and that these aquatics might give origin to the compact moss that now appears above the fibrous.

General de Jean is of the same opinion. He thinks that all mossy grounds were once covered with water; that aquatic plants, by their continual growth and decay, have filled up the space occupied by the waters, and given origin to moss; that, of course, these aquatic plants may still be detected in these mosses.

The above accounts corroborate this opinion ; but the following considerations will, I trust, place it beyond the possibility of a doubt, that many mosses have been originally lakes.

1. Many of the deepest mosses in Europe are still in a liquid state. The deepest moss I have ever heard of, is that described by Mr Aiton in his essay. He says, that he lately attempted to sound Moss Mulloch in Avendale, and sunk wooden rods upwards of 40 feet without finding the subsoil. From the manner in which he describes this operation, I am led to conclude that this moss must be very soft, and in a semiliquid state.

The deepest moss in this neighbourhood is the Dullatur bog. Many attempts have been made to sound it. In some places it is so deep that these attempts have been fruitless. It seems to be precisely in a similar state with the deepest mosses in the valley of the Somme. The surface is covered with a solid but elastic mass of fibrous matter ; below this is a black semiliquid pulpy moss : in one spot the water appears on the surface like a contracted lake.

Many of the deepest mosses on the Continent are of a similar description : Mr De Luc delineates them with all the minuteness of a careful observer. He says, that " the deepest mosses in Bremen are so " *thin*, that they may be considered in a liquid state : " that they are often of the consistency of a pulp " like rags preparing for paper : that the surface, " though more compact, is only a slight matting, not

"safe for man or beast to tread upon: that no person dare venture on them without planks: two of these planks is all that is necessary; each of these has a cord attached to it. After the traveller has laid down the first plank on the moss, he passes along it, dragging the second after him by the cord; this second he lays to the end of the first, and, lifting it, he carries it along with him in the same manner."

These mosses seem to be of the same liquid consistency, even to the greatest depth: for he adds, that "he sounded them with an instrument which he carried along with him; that, without any effort, this instrument sunk by its own weight till it reached the clay 36 feet deep."

If the deepest mosses be still in a semiliquid state, the probability is, that at a former period they were lakes.

2. These mosses thus pent up in the vallies are often swelled to such a pitch that they burst forth wherever there is a declivity, and overflow the adjacent fields. De Luc observes, that "this is no uncommon event on the Continent; that, on the contrary, it is a danger dreaded by the inhabitants of the mosses themselves, and also of the adjacent vallies;—

"By the inhabitants of the vallies, for these are sometimes overflown to a considerable depth with this liquid stream of flowing moss, when it bursts its former bounds. It is no less dreaded by the

" inhabitants of these mosses, for whole plots of this " spongy substance, when gorged up, are sometimes " swept away like a floating island, with all its trees " and cattle, and houses, and inhabitants. The ex- " ternal coat," he says, " is of a more solid consis- " tency than the internal mass; yet, like a torrent " of lava, when an opening is made, it will run like " a river, even though the surface seems not to " move."

It is almost unnecessary for me to add, that the inhabitants are under the necessity of using precautions to prevent such fatal accidents; they fix down the surface of the moss by large stakes and beams, driven into the subsoil, &c. &c.

Far less is it needful for me to specify and describe the numberless instances of similar accidents that have happened at different times in different kingdoms.

In Scotland, a number of accidents of this kind have occurred. That of the Solway moss is universally known; that of the Aberdeenshire moss, described by Dr Anderson, and of the moss of Kincardine, in the years 1792 and 1793, described by the Rev. Mr Tait, are well ascertained.

In Ireland, similar instances might be mentioned; as that of Charleville moss, in 1697, and that at Gartenmalach, described by Dr Ledwick as a kind of bog-dropsy.

The moving moss of Lancashire and that of Morle, in England, might likewise be pointed out.

The alarming inundations at Wishafen and other places on the Continent might also be mentioned.

But, without describing these, I only observe, that the probability is, that all those mosses which appear in this semiliquid state, have at one period been lakes.

3. It is a well known fact, that many of our deepest mosses are still in so liquid a state, that, like a lake swelled by a flood, they are frequently gorged up above their ordinary level. Their surface, by this means, alternately rises and falls, although they do not thus burst forth in a torrent. Almost every peasant has observed this; it is unnecessary to point out instances of it.

None can deny that many mosses, when drained, sink considerably, and some many feet. Dr King says, that the bog of Castle Forbes sunk 30 feet; Dr Mills allows that it sunk upwards of 15. This is a clear proof that this moss was in a semiliquid state. Upwards of one-half of its depth was filled with water; and many mosses are still in the state of lakes, only covered over with a thin matting of moss on the surface.

A very great proportion of the mosses in Holland and Friezland are of this description. They are accordingly all highest in the centre, that is, where the water has the least egress or opening. Picard observes this, and adds, that, by an accession of stagnant water, and the growth of aquatic plants, they rise and swell rapidly; they are, too, so porous and spongy, that they are called *Hol bol los*, that is, trembling

ground; or, *Het land leeft*, i. e. living land that moves.

In the Scotish dialect there is a similar distinction of quick and dead moss. By quick moss, however, is not meant, as Dr Anderson would insinuate, moss that lives, vegetates or grows, but that which trembles and shakes, or in which a person will sink. The word is used metaphorically in other instances. By quicksands are meant, in the same sense, moving sands, in which a person sinks, or may be quickly swallowed up.

The quaking bogs in Ireland are of the same kind with those in Holland called living land, and in Britain quick-moss.

4. Another proof that many mosses have been originally lakes, is, that they contain the remains of the shell-fish and other exuviæ of animals which exist only in marshes or pools.

5. After the peat has been dug from the surface, many mosses again revert to their original state of lakes.

Degner describes the mosses in the neighbourhood of Utrecht. He says, "that, after digging a foot "and a half deep on the surface, they come imme-"diately to the subterraneous water: that when the "moss is entirely dug out, all that remains is an ex-"tended lake: that, in 20 or 30 years, 60, 80, or "100 acres are sometimes cleared of moss in this "way." He adds, that,

"However sad and gloomy, and even dangerous
"these lakes may be, they are not entirely useless.
"After the moss is removed, the waters become
"sweet, and fit for every domestic purpose. Fish
"of the best quality abound in these lakes. These
"are supplied by the canals and rivers that commu-
"nicate with the mosses; and 100 families some-
"times subsist by fishing on one such lake."

He observes farther, "that these lakes are some-
"times drained at an immense expence, and con-
"verted into a rich soil. They first surround the
"lake with a mound, to prevent the surface-water
"from flowing into it. By wind-mills they then
"drain off the water of the lake: the little moss that
"remains at the bottom they burn; by this means
"the whole becomes a fertile soil.

"So that these mosses may be seen undergoing
"the following changes: They first appear as a rich
"meadow; then turf is dug from under this: a rich
"supply of wood is often found under the turf.
"When these are all removed, the whole appears
"as an extensive lake, abounding with fish; and, at
"last, when this water is drained off, it is converted
"into a rich and fertile soil.

"To drain off these waters requires an immense
"expence. In the year 1728, a certain nobleman
"drained 800 acres by four mills; these cost him
"30,000 florins Dutch; and, before the whole was fit
"for culture, it cost him 200,000 florins: besides,

" these mills required to be kept up at a great ex-
" pence annually, to carry off the superfluous water.

" The attempt to drain such lakes sometimes fails
" altogether ; for, when the moss on the original
" surface is removed, the spongy bottom called *darry*
" (a particular species of moss which shall be de-
" scribed) rises up, and leaves a lake sometimes 30
" feet deep. To drain this is impossible; for, as such
" lakes are often far below the level of the sea, when
" it bursts its banks the whole may be overwhelmed
" in a deluge."

It is impossible to ascertain what progressive changes such mosses may have undergone. The wood found in them renders it probable that they were originally forests. The darry at the bottom (which consists almost entirely of reeds and rushes) would lead us to suppose, that these ruined forests had been converted into marshes in the next stage, when these rushes and reeds grew. The depth of the moss, and the liquid state in which it is still found, and their reverting again into lakes when the moss is removed, render it highly probable that they were, at a future stage, deep pools of water. In these pools it is probable the aquatic plants afforded materials for the black, loose, pulpy moss.

The account he gives of the different strata of these mosses corroborates this conjecture. He says, that the first stratum that appears after the surface is removed, is a blackish red moss, very tenacious, but soft and pulpy ; this yields the best fuel, and is ge-

nerally about two feet deep. This appears to me to be produced by the aquatic plants which must have flourished when the whole was in the form of a lake.

The next stratum is somewhat redder, equally tenacious, but partly fibrous. This appears to me to have been formed partly by the marshy plants, and partly by aquatics.

The lowest stratum is much redder; it is so fibrous and spongy, that it appears to consist entirely of rotten wood: it is the worst fuel. This seems to me to have been formed of the ruins of the forest, when the whole was converted into a morass.

Some mosses in this neighbourhood exhibit the same proofs that, at one period, they were lakes. After digging four, six, or ten feet deep, the subterraneous water is laid open; this often rushes up with such rapidity, that the pit is filled to the surface before the person who dug it can escape out of it.

Degner states it as a well known fact, that, in many instances, peats are dug where a navigable lake once existed; not only in Zealand, which once lay under the ocean, but in many places, especially in Oldhampton.

This leads me to notice another circumstance that confirms this:

6. That boats and nautical instruments are often found in the deepest mosses.

It is superfluous to specify all the instances of this. I shall name a few.

Degner says, that pieces of ships, nautical instruments, oars, &c. are found in the Dutch mosses.

Girard, in his history of the valley of the Somme, mentions that, in the lowest tier of that moss, was found a boat loaded with bricks.

It seems to me inconceivable how ships, boats, and nautical instruments could exist in the depth of mosses, on any other supposition than that these were at one period navigable lakes, or arms of the sea.

I have only to add another circumstance that leads to the conclusion, that many mosses were at one period lakes.

7. The name they bear implies this.

Mons. De Luc, in his letters to me already alluded to, observes, that some of the dales on the Continent, now filled with peat, retain still the German name *See*: that the meaning of this word is *lake*: from whence he concludes, that these mosses were lakes in known times.

Picard observes, that many mosses on the Continent still bear the name of *poel*: that this is a proof that, at one period, they were pools or lakes.

It is almost unnecessary for me to add, that the words *fen*, *marsh*, and the terminations *brook*, *maer*, *goor*, &c. which are so prevalent over Europe, indicate the same thing. Innumerable mosses, and many cultivated low levels, bear these names. Degner takes particular notice of this.

He says, that many regions abounding in mosses are called *veen*-land, *veen*-grond: that *veen* signifies a muddy marshy soil. Hence the Saxon word *fenne*, and the English *fen*.

He says, that many other regions are called *brock*-land; that *brock* signifies a *lake*; that the names of many villages in Holland and Friezland have this termination: hence the inhabitants, in the time of the Romans, were called *Bructeri*, or the inhabitants of the laky country.

The words *moer*, *moeras*, *marse*, *mershe*, *maer*, he observes, signify a lake or marshy ground. *Moer* signifies that on which brushwood and ligneous plants grow; hence innumerable places are called by names having this termination, as Gravenmoer, Thesenmoer, &c. and the inhabitants were called Morini by the Romans.

Morass, or *moeras*, or *marse*, &c. denote a lake or laky country: He says they are derived from the verb *meer*, signifying to dissipate into small particles; because the waters which overflow these low vallies, by subsidence diffuse small particles of earth over them. That the German, French, Saxon, and Anglo-Saxon, names of the sea, are derived from this. In the German it is called *mere*; in French *mer*; in Anglo-Saxon *mere*; in Saxon *maer*; in Spanish *mar*: hence the inhabitants of these countries were called by Pliny, Marsatii; by Tacitus, Marsaci: and hence the names of places still bear this or similar

terminations, denoting that lakes abounded where mosses now occupy their place.

He observes, too, that the Flemish word *gor* or *goor* is the name of many mosses : that *gor* signifies a lake or laky soil : that the adjective *goor* signifies putrid, fetid, or subacid : that *vergooren* signifies to become acid by being stagnant, from the verb *goer*, *gier*, *geren*, to ferment : hence the Saxon name *gyra*, signifying a lake or marshy soil where waters ferment, and *goor* signifying a land new formed by alluvion : hence Cæsar calls the inhabitants Gorduni, *goor* signifying a lake, and *duyn* a sandy hill.

Girard, in his history of the valley of the Somme, takes notice of the etymology of that name : He says, that Somme, in Celtic, signifies water kept within bounds ; that the Celtic word *mos* signifies water that spreads : hence the name *Mosa* to that river, as it frequently overflows and stagnates.

As the original Celtic name *mos*, is descriptive of the origin of peat, I have preferred it, and still am determined to retain it. I know that Dr Walker says, that peat is a word used in Scotland and in the north of England; that, till of late years, it has seldom been used by any English author : this to me is of little importance ; nor shall I attempt to prove, that it was used by Leland in his Itinerary, as early as the year 1712, and by Dr Hans Sloan about the same period.

Granting that it is a Scotch word, it is a word universally understood in Britain ; and when we speak

of peat moss, the meaning is equally obvious, as when we use the word peat earth, which is not in itself descriptive, or the word *turbary*, which is of foreign derivation.

As peat is descriptive of the distinguishing quality of that substance, inflammability, and moss, of its origin or situation, I think it preferable to retain it.

8. It is almost unnecessary to add, that those mosses from which soda and salt turf are dug, have, at one period, most probably, been salt lakes, or arms of the sea.

I have already shewn, that there is every probability that the lower parts of the coasts of Picardy, though now covered with moss, were once overflown by the ocean. I only mention, that the soda which may be extracted from the peat in that district, renders this highly probable.

It seems absolutely certain, that many of the mosses in Zealand have once been lakes of salt-water, or arms of the sea. Braak truf is accordingly dug out of these lakes; the water in them, like the turf, still contains salt. These turfs, when burning, emit, of course, a fetid odour; this odour is disagreeable, and by the Zealanders deemed dangerous; it communicates a livid death-like colour to the skin; it occasions a sickly squeamish feeling; sometimes it brings on a syncope and fainting fits: to remedy this, they sprinkle salt on the turf while burning. Degner, however, is of opinion, that this, in place of a remedy, only increases the evil: he thinks, that the white ef-

florescence that forms on the turf, is not owing to sulphur, as some have supposed, but to the salt it contains. As a proof of this, he says, that salt thrown on the turf emits a similar blue flame: that Hoffman, in distilling common salt with sand, observed the same whitish yellow efflorescence on the retort.

Many, if not most of the mosses in Friezland, appear to have originated in a similar manner. Much of that country, like Holland, still lies below the level of the sea; none of it rises far above that level; and the soil, in general, is so soft, that no solid foundation can be found for building their houses upon; they are under the necessity of driving piles into the solid subsoil, on purpose to form a proper foundation. Many of the mosses in that district, are, like the other Dutch mosses, impregnated with salt; they abound in what is called *braak torf*, or salt peat.

This is a proof that the site of these mosses was originally occupied by the ocean; else, whence comes the quantity of salt contained in them? This supposition becomes more probable, when it is considered, that much of that country has been reclaimed from the ocean, and that many different districts of it have been overwhelmed by inundations of the deep.

If it be granted, that all those mosses in Europe which are still in a semiliquid state, or have burst their barriers, or alternately rise and fall, or revert into lakes when the moss is removed, or contain pieces of ships or nautical instruments, or bear the name *poel*, &c. or contain salt and soda, were once

lakes, this list must include some of the largest and most extensive mosses in the world.

Having endeavoured to shew that moss is renovated, with the circumstances and time requisite; having also endeavoured to ascertain the aquatic plants which promote this renovation; that the same plants have contributed to the original formation of moss; and that many lakes in the north of Europe have thus been filled up with this substance, it only remains for me to shew,

SECTION VII.

That aquatic plants may be traced in most, if not in all moss. The organization of these is often so entire, that we can easily ascertain the distinct species that prevails.

I regret that I have not been able to collect such a variety of specimens as I expected. I am confident, that if a complete collection of these were made, there would be no difficulty in discriminating the distinct plants, of which all fibrous moss is formed.

I shall mention a few facts, which may tend to elucidate this subject.

In the *first place*, the conferva has been shewn to promote the renovation and growth of moss. This may still be traced in recent mosses; but in those of a more remote origin, it is in vain to expect this: the organs of this species are so small and delicate, that they cannot be distinguished after they have undergone a partial disorganization.

There are other tender plants of this description: The leaves of the lemna, and the delicate organization of this plant, cannot continue long distinguishable, when incorporated with such a mass of extraneous matter.

The byssus, &c. whose roots are of a hair-like or capillary form, may be more distinctly traced; and in the soft pulpy black moss, these roots, &c. are the cause of that filamentous form and appearance it assumes.

2. The organization, however, of other aquatics, may be, and has been ascertained with certainty. The hypnum is of this description; it may be traced deep in moss in a distinct organized form.

Mons. Faujas de St Fond mentions a beautiful specimen of moss as an instance of this. In the valley of Sanchy, at the depth of seven or eight feet, a moss was dug 11 feet thick; this seemed to be composed solely of the hypnum. He says, that "the species "resembled the hypnum adunum Lin. There seem-"ed to be no mixture of any other plant in this

"moss excepting some leaves of trees, equally well "preserved." He observes farther, that "the "depth of soil above the moss, and the many layers "of spongy elastic matter in the moss itself, clearly "evince that it must be of very ancient origin, and "must have remained in this state for many ages; "yet the organization of the hypnum is so distinct "and entire, that the stems, branches, and leaves are "all discernible."

The conclusion is obvious, that this plant has contributed chiefly to the formation of the moss he describes. Dr Walker thinks that the hypnum fluitans is one of the most luxuriant of this species. He says it grows two or three feet long in a season; and that, in the course of 20 years, it has formed a thin stratum of flow peat in Annandale.

3. Aquatic grasses may also be traced in moss. Poiret observes, that the leaves of these are dry, and the stems somewhat coriaceous; that, on this account, they preserve their organic structure long. Degner observes, that these, by rushing up in pits, contribute to the renovation of the moss. Though this be of recent origin, yet it yields fuel. It is light and spongy at first, but when left for 30 or 40 years it is consolidated into excellent turf.

When thus consolidated, he observes, that, upon examination, it consists of nothing but grasses with a small mixture of moss and mud. Hence it is called *groos*, or *groes*, i. e. grassy; and the peat dug from it is called *hey turf*, or grassy peat.

Dr Collet describes the best Berkshire peat as a compost of the branches, twigs, and leaves of trees, with grasses, straw, plants, and weeds.

Dr King gives a similar account of the Irish mosses. He says, that "Ireland abounds in springs. Grass "and weeds grow rapidly at the out-burst of these. "In winter, these springs swell and loosen all the "earth about them; the sward, consisting of the "roots of grasses, is thus lifted up by the water. "This sward grows thicker and thicker, till at last it "forms a quaking bog. As it swells higher and "higher, the grass and roots become more putrid: "mixed with mud and slime, the whole acquires the "blackness and consistency of a turf bog."

I will not attempt to enumerate the aquatic grasses that may be expected in moss. Doubtless, all the varieties may be found; and a careful observer, by the use of a good microscope, may easily ascertain the particular species found in any peat.

4. Rushes and reeds, I have shewn, contribute to the original formation and subsequent renovation of moss; it is certain, that they can still be traced in that substance in an organized state.

I have seen whole masses of moss that consisted almost entirely of rushes. Their original form and figure is still retained; they presented precisely the appearance as if they had been petrified, only, the coagulum, or cement, that bound them together, was black and soft. The moss on the surface of the valley of the Somme seems to be similar to this. Gi-

rard says it is loose and friable; yet the roots of reeds and rushes may be distinctly seen in it. Lambardie, in his view of the origin of this moss, says that the marsh is all covered over with rushes and reeds on the surface. He supposes, that, when the banks that crossed the valley and stemmed up the water were cut, these waters issued out; that this crust of roots reached the bottom; that the whole, by condensation and decomposition, were converted into moss.

Reeds may be traced in many mosses; especially in that species which seems to be peculiar to Holland, called by the Dutch *darry*. It is found most frequently along the sea coast. Degner says, that after the moss is extracted, they frequently come to slimy mud at the bottom; that sand is seldom discovered there. At other times a light, porous, spongy bottom, full of grasses and reeds, is laid open; this is called *darry*, or *derry*. In the heat of summer, this substance often rises up to the surface of the water in large masses; sometimes these are 100 feet long, by three to 10 feet deep, though this seldom happens in winter *.

* In the lake Derwent Water, a similar substance is sometimes found. It appears in the form of floating islands. These rise from the bottom of the lake: sometimes one and sometimes two appear in the year: Some sink to the bottom again in the space of 24 hours; others swim on the surface for six weeks, two months, or even longer: One rose in 1798, which was 180 yards long and 50 wide: Some of them have been found 21 feet thick.

This substance swims along the surface of the lake, and is, on this account, called *dryvend*-land, for the inhabitants can enter upon it, and move it about like a vessel. If it rest in one place for a number of years, it is covered with aquatic plants, reeds, and mosses. It is combustible; but the quality of the turf is inferior.

On account of its being thus moved about, it is often found in the sea. Hence the Dutch have supposed this and other kinds of mosses to be a marine production. Degner, however, observes, that it has

There can be no doubt that the substance of which these islands consists is a species of moss; for, excepting about two feet of the surface, (which consists of mud), the whole appears to be a congeries of leaves and roots of trees and other plants.

And it seems probable, that the moss found in this place is similar to what is called *darry*. Were I to hazard a conjecture, it would be this, that the name of the lake denotes this. *Darrie*, *derrie*, or *darink*, signifies a combustible matter: It is derived from the Danish word *darien*, to burn.

Derwent water, or Darink water, may denote the lake containing *darry*, or inflammable matter; but I mention this merely as a conjecture.

I only observe, that similar floating islands have been seen in Kinson Pool in Staffordshire. Dr Plott says that they consist of a kind of stringy bituminous earth. He speaks of two, about 20 feet broad, by 30 or 40 long, which appeared in 1680.

It appears that similar floating islands have existed since the days of Seneca and Pliny. Both these authors take notice of a lake near to Actila, a town of the Sabines, in which was a floating island.

unquestionably been carried to the ocean by alluvion. He thinks it probable that it may have been thrown out from the sea into some of the lowest districts of Holland, and afterwards covered over with moss and mud; but he adds, that this is by no means a proof, either that it was originally formed in the ocean, or that all moss is a marine production.

He thinks that, as it is certain that many mossy levels have been overwhelmed by the sea, this species of moss might thus be elevated and torn up by the winds and waves, and afterwards swept into the ocean. Hence, he observes, that it is only this spongy reedy turf that is found there, just as trees are found carried thither by alluvion.

This kind of moss is found at the bottom of the sea, near Antwerp, at the depth of 20 feet; and likewise in the bottom of mosses and lakes at Ziric Zeam. It is said to contain a liquid bitumen, and a portion of salt: Hence it is called *braak* turf. The nearer it is to the sea, the greater is the quantity of salt it contains, and the odour it emits is more fetid.

Whether the moss found in the bay of Oban, on the coast of Cornwall, Wales, and Cumberland, &c. &c. be similar to this, I have not had any opportunity of knowing. It is certain, however, that rushes and reeds contribute their part to the formation of moss. It is impossible for me to ascertain the particular species of each that prevails most in any particular spot; in general, however, we may expect the following species:

Scirpus lacustris, or the common bulrush;
Schænus mariscus, or prickly bog-rush;
Juncus conglomeratus, or the common rush;
Arundo phiagmites, or reed;
Scirpus cæspitosus, or deer's hair;
Juncus squarrosus, or wire bent;
Juncus articulatus, or spret, &c. &c.

And it would be desirable that every person who examines rush peat, would endeavour to ascertain the particular species of rush or reed that prevails in it.

5. The leaves, roots, and stems of the iris may often be traced in moss; every careful observer must have seen instances of this. These may be traced to a great depth, especially in black pulpy moss.

6. Heath may be likewise traced in moss. Mr Aiton is of opinion that heather peat does not exist. He allows that it grows on moss in almost every state we find it: But he says that it is extremely slow in its growth, and as slow of decay; that the bulk of earth it yields is so small as to be almost imperceptible; and he does not believe that the thousandth part of any moss was ever composed of decayed heather.

It cannot be denied that, on dry moorish grounds, heath is slow in its growth; yet, even in such situations, it contributes to the formation and renovation of moss. De Luc accordingly observes, that, in the plains of Twickel, it promotes the formation of peat. He says, that when the peat is dug out of the pools, the sand, which forms the subsoil, appears pure;

that it is speedily covered with water; that heath springs up spontaneously, and with *great rapidity* in these pools; that this water and heath constitute their part to the formation of new moss in such places; that even the rain-water which falls on the heath, when it is allowed to STAGNATE, leaves a sediment similar to moss, and acquires the brownish tinge of moss water.

This, however, is not the point I aim to establish. My object is to shew, that heath may be, and is detected as a component part of many mosses: it is even found in an entire organized form in those of the most remote origin. I have seen peat dug out of mosses in this neighbourhood at the depth of four and five feet, one half of which was composed of heath; the roots, branches, and even seeds of the plant could still be distinguished. Mr Tait, in his account of Kincardine moss, observes the same thing. He says, that, at the bottom of that moss, which is in some places 14½ feet deep, bunches of heath are found, far more entire than those found nearer the surface: that the roots of this plant are often seen fixed in the clay subsoil. Williams, in his essay on coal, describes a species of heath peat in the following words: "A foot and a half of the surface consists entirely of "the branches, roots, blossoms, and seeds of heath, "apparently not in the least decayed; the second "stratum below this is the same, only beginning to "decay; the third consists of flow moss; the last is "perfectly black, and of a close texture." He says,

that this is a description of moss Flanders, moss Kinhaw in Ardnamurchan, of Solway, and most of the Highland mosses.

It is not enough to invalidate this argument to say, that the heath is not reduced to earth; or that, because it retains its organic structure, it does not contribute to form moss. Upon the same principles, every plant I have named, whether aquatic or ligneous, may be banished from the list, for they are all found in an organised state; and the organization of them is often as entire as heath; yet all of them yield an inflammable earth; in other words, they form a part of moss.

Nor is it a sufficient objection, that heather may have grown uninterruptedly for ages, and yet no moss has been formed under it. Other circumstances, as I shall shew hereafter, are requisite to the formation of moss than the growth of those plants which form it.

On dry moors, such as those immense regions called *geest* on the Continent, where the water is not allowed to stagnate, the formation of moss, either by heath or any other plant, must be slow and imperceptible; but, on level plains, the growth of heath is rapid, and the formation and renovation of moss rapid in proportion.

7. Aquatic mosses may be detected at all depths in almost every peat; this is a very numerous class. Upwards of 300 species of mosses have been detect-

ed; they flourish in all low marshy soils where peat is found.

It is reasonable to expect, therefore, that they may all be traced in moss; accordingly, many peats seem to consist of nothing else.

King, in his account of the Irish bogs, says, that aquatic mosses abound more in Ireland than in any other kingdom: that the light spongy turf is nothing but a congeries of these: that he has frequently observed this before the turf was sufficiently rotten. He adds, "truly I impute the formation of the red "or turf bogs chiefly to this. On examining a sec- "tion of such mosses, this will appear obvious. The "sphagnum, and other moss plants, may be seen "growing fresh and vigorous at the surface; a foot "deep they exhibit marks of decomposition; and "deeper still, they are completely disorganized."

The woolly turf which Degner describes is probably of this description. He says, that it is full of filaments and organized matter: that it is therefore called by the Dutch *locke*, i. e. wooly, or *dractagtig*, i. e. filamentous.

That which is found near Craneberg is certainly similar to the red bogs of Ireland. It seems to consist almost entirely of mosses. Degner says he examined it. Besides pure aquatic moss, of a light yellow colour, and a few filaments of aquatic grasses, he found nothing else.

Mr De Luc, in his first letter to me, gives the following account of a similar turf. He says,

"I have brought a specimen of some peat of the "country of Shleswig; it has hardly any thing else "in its composition, than a ramified common moss. "I have let some of it stand a whole year in a bason "of water, always repairing the loss of water by eva-"poration, yet it did not change its shape, or tinge "the water: at last I took it to pieces, which was "but to force the separation of the interwoven threads "of the moss. I washed these separate tufts in the "water in which it had been steeped: though this "gave a turbid appearance to the fluid at first, yet "after being left to settle, it became clear. The par-"ticles mixed in the water, were of two sorts; one "of these floated on the surface, the other sunk to "the bottom of the bason. The former were only "small bits of moss, which had not undergone the "process of the separation of the molecules; the "other was a brownish powder, probably the divid-"ed molecules which produce the peat mud, and are "of a greater specific gravity than water.

"If the broken pieces of this specimen, (which "probably would produce the same effect after be-"ing sunk in water and more divided), can be of "any use to you, I will send to you with pleasure."

Ribancourt describes two species of peat found in France, similar to the above. The first is white and heavy, filled with shells, and mixed with much earth; this is called earthy peat. The second is brown, of a bright hue, very light and porous, full of openings;

it precisely resembles a collection of fog; it is therefore called *mossy* peat.

Both of these are of little value; they are seldom used as a fuel.

I have examined several mosses with care, and I am confident, that all the red mosses, or those of a reddish yellow, sometimes called flow moss, are of this description. Ket moss is similar to this; and that called in Ireland *old wives' tow* is of the same kind.

In place of specifying any particular moss, I would call the attention of the reader to this point. Let him examine this spongy light coloured peat, in the manner De Luc describes, and he will find, upon inspection, especially with a microscope, that it consists chiefly of a congeries of aquatic mosses.

I say mosses in general, for it were an endless and idle task to specify the particular classes. All the different species may be expected; and I have no doubt, but with proper care and minute attention in making experiments, they may be discriminated from each other.

There are some of these so bulky, that they can easily be detected by the naked eye; of this description, are the sphagnum, palustre, polytrichum commune, &c.: others are so minute, and their organization is so delicate, that they require the application of the finest microscope to detect their structure; of this description are the conferva, lemna, &c. &c.

I have only to observe, that Mr Aiton looks on this as a species of peat rarely to be found: He says, that it is only to be met with in a few lochs, flanks, or standing pools of water; that it scarcely merits notice.

From the most accurate and extensive researches I have been able to make, I am disposed to think otherwise. It seems to be the prevailing species over all Ireland; immense tracks of that country are covered with it. In Friezland, Brandebourg, Brunswic, Shleswick, Holland, &c. &c. it appears from Degner and De Luc to prevail. In many of the vallies of Scotland it is to be found; and perhaps no peat, of any particular description, (that is, where a particular species of plants abounds in it), is found in greater quantity or extent.

It were an easy task to swell the list of aquatic plants that have been detected in moss. I decline to particularize these any farther, and dismiss this point with one general remark, *that all the aquatics which flourish in mosses, marshes, or lakes, may be expected to be found.* Perhaps, by farther investigation of this important subject, a collection may be made from mosses of different kingdoms, exhibiting all the varieties of these plants; and why should not such an attempt be made? The subject is surely of sufficient importance; and it were worthy of any university or society in the kingdom to undertake the task. The expence and trouble of it is too much for any individual; to a society these would be trifling. I for

my part undertake to furnish a collection of specimens which deserve a place in any museum.

It may be useful to some of my readers to furnish a list of those plants whose growth is most rapid: De Luc says, that Mr Oeder is of opinion, that the following, by the rapidity of their growth, soon bury in our mosses the heath and other shrubs, and the grasses, reeds, and rushes, of our meadows, viz.

The conferva, with its green clouds;
The byssus and tremella; and, above all,
The sphagnum palustre.

Among the grassy plants which grow in abundance, he enumerates the eriophorum vaginatum, eriophorum polystachion, and carex cæspitosa.

Dr Walker, in his Essay on Peat, gives the following list of plants which generally occupy and cover the surface of moss in Scotland:

1st Class. *Noxious.*

1. Pinguicula vulgaris; white rot.
2. Hydrocotyle vulg.; marsh pennywort.
3. Drosera rotundifol.; } red rot.
4. ——— longifol.; }
5. Anthericum ossifragum; Lancashire asphodel.
6. Ranunculus flammula; spearword.
7. Caltha palustr.; marsh marigold.
8. Oenanthe crocata; hemlock drop-wort.
9. Pedicularis sylvatica; louse-wort.
10. ——— palustris; marsh louse-wort.
11. Myrica gale; gale.

2d. *Plants of no known use.*

1. Schænus nigricans; black bog-rush.
2. ——— albus; white bog-rush.
3. Scirpus palustr.; club-rush.
4. Juncus campestres; field-rush.
5. Cornus suecica.
6. Primula farinosa; bird's eye.
7. Lysymachia tenella; purple moneywort.
8. Pyrola minor; lesser wintergreen.
9. Lycopodium clavatum; wolf's claw.
10. ——— selago; fir-moss.
11. Sphagn. palustr.; bog-moss.
12. Polytrich. comm.; goldclocks.
13. Marium palustre.
14. ——— fontanum.
15. Bryum paludosum.
16. ——— scoparium.
17. ——— cæspititium.
18. Lichen rangiferinus; rein-deer moss.

With many lesser plants of the mossy tribe.

In Moss Water.

1. Utricularia minor; hooded milfoil.
2. Potamogeton natans; round leaved pond-weed.
3. Comarum palustre; marsh cinquefoil.
4. Carex vesicaria; bladder-grass.
5. ——— turgida.
6. Chara tomentosa.
7. Hypnum fluitans.

These, he observes, grow up in peat pits, and, by their rapid growth and decay, fill them again with new formed peat.

3d. *Plants of some Economical, Medical, or Mechanical use.*

1. Vaccinium occycoccus ; cranberry.
2. Rubus chamæmorus ; cloudberry.
3. Menyanthes trifoliata ; marsh trefoil.
4. Schænus mariscus ; prickly bog-rush.
5. Scirpus lacustris ; bulrush.
6. Arundo phragmites ; common reed.
7. Juncus conglomeratus ; common rush.
8. ——— effuscus ; hard rush.
9. Tormentilla erecta ; tormentil.

4th. *Gramineous Plants, affording Hay.*

1. Acra cærulea ; fly-bent.
2. Agrostis stolonifera ; marsh bent-grass.
3. Cynosurus cæruleus ; blue dog-tail grass.
4. Juncus articulatus ; spret.
5. Carex cæspitosa.
   ——— limosa.
   ——— trigona.
6. Carex gigantea.
7. Holcus lanatus ; soft grass.
8. ——— mollis ; creeping soft grass.
9. Triglochin. palustr. ; arrow-headed grass.

5th. *Plants serving for Pasture.*

1. Scirpus cæspitosus; deer's hair.
2. Eriophorum polystachion; } bog cotton, or moss-
——————— vaginatum; } crops.
3. Nardus stricta; bent.
4. Agrostis capillaris; fine windstraw.
5. Aira flexuosa.
6. ——- montana.
7. Juncus squarrosus; wire-bent.
8. ——— flexuosus.
9. Erica vulgaris; heather.
10. ——— cinerea; } bell heather.
11. ——— tetralix; }
12. ——— incana; downy heather.
13. Carex atrata, and many small species.

6th. *Shrubby and Arboraceous Plants.*

1. Vaccinium myrtyllus; blae-berry.
2. ———— uliginosum; great ditto.
3. ———— vitis idea; red ditto.
4. Andromeda polifolia; marsh rosemary.
5. Arbutus uva ursi; stone-berry.
6. Juniperus communis; juniper.
7. Empetrum nigr.; crow-berry.
8. Salix pentandra; sweet willow.
9. ——— glauca: and smaller species.
10. Betula alba; birch.
11. ——- alnus; alder.
12. Scorbus aucuparia; rowan.
13. Pinus sylvestris; Scots pine.

The conclusion from this is obvious. If these plants are found growing on mosses, it is natural to expect that they may be traced in all their varieties, and in all the various stages of decay; and that such plants, whether in a state of organization or disorganization, have contributed their part to the formation of those mosses in which they are found.

I may add, that it is perhaps possible to ascertain the state in which any moss was when the several strata of it were formed, by discriminating the plants which prevail in it.

Sennebier observes, that the different species of aquatics require different soils. The nympheæ grow up in lakes of a firm bottom; in loose bottoms the chara abounds; the carex delights in those marshes which are dry in summer, but wet in winter; in deep waters, the sphagnum flourishes; the hypnum abounds in shady forests; gentiana lutea, veratrum, epanula drabæfolia, anchusa, stachys, fusca, prevail in meadows.

If this account be correct, (and surely it proceeds from high authority), we may, perhaps, make the following conclusions: That, where a stratum of moss abounds chiefly with the nymphea, the subsoil is firm; where the chara prevails, it is loose: That where the carex abounds, the moss, at the period in which this stratum was formed, was flooded in winter and dry in summer; where the sphagnum prevails, it was in the state of a lake: That where the hypnum forms the chief materials, a shady forest once

grew: hence leaves of trees were detected by St Fond in the lowest stratum he describes, p. 165 and 166.

And that where meadow grasses are chiefly to be traced in moss, that moss was in the state of meadow when this stratum was formed.

It may be proper to endeavour to ascertain some of the distinguishing qualities of those plants which promote the formation or renovation of moss, or which are detected in it.

This subject I reserve to

SECTION VIII.

Dr ANDERSON asserts, that moss produces few vegetables; that these tend rapidly to decay; that all vegetable substances, when dead, decrease in bulk, so that they do not occupy above one hundredth part of the space they did; that moss does not produce one hundredth part of the crop of a fertile soil.

We are now, in some measure, prepared to meet the Doctor; I shall, therefore, consider each of the above assertions.

I. That moss produces few vegetables is not strictly true. The foregoing list of plants that flourish even on our Scottish mosses, shews the contrary. It is true that it produces only marshy and aquatic plants, but a great variety of species of these may be seen in every moss. Almost all the varieties that flourish in marshes and lakes may be traced also in moss, and have therefore contributed to the formation of it; so that, with equal propriety, the Doctor might have asserted that the former produce few vegetables as the latter.

On decaying or decayed woods, which I have shewn lay the foundation of many mosses, a great variety of the musci flourish: some of these are rapid in their growth. De Luc mentions, that he has sometimes seen a matting of these a foot thick at the roots of rotten trees, or under their shade. Cordiner says, that the fallen trees of Glenlin are deeply immersed in these plants. The Earl of Cromarty also observes that the ruined forest he describes was all covered over with green moss.

It is of no avail to the Doctor's argument to say that this is no proof that these plants flourish in mosses. It is a proof of the point at issue, that they may have contributed largely to the original formation of them: for, if these ruined forests have laid the foundation of many of these mosses, the plants above described must have mingled with the mass, and added to it.

Even though this were doubtful, it is certain that many of the musci flourish in low marshy grounds; the sphagnum, &c. flourishes even in moss pits.

It may also be observed, that many of these plants are very rapid in their growth. I might have rested the evidence of this on the testimony of Mr Findorf, as stated in the 4th section of this essay. I may add, however, that De Luc takes particular notice of the rapidity with which aquatic plants rush up in the mosses of Bremen. He says, that it is hardly credible how speedily one tier succeeds and buries another, heaping thus layer upon layer of moss.

Some of the mosses in particular rush up and arrive at maturity in a very short period. Hedwidg sowed the seed of koelcreutera hygrometrica; in seven days the plant sprung; the roots appeared when the seed was placed in water in three days; in eight days the leaves were formed; and the plant was complete in twenty.

3. Some of these, too, flourish in the coldest climates, and in the coldest seasons of the year. Darwin in his Phytologia says, that the rein-deer moss vegetates under the snow, when the temperature is as low as 40 Farenh.

Even on the highest mountains their growth is rapid. De Luc mentions that, on the hill of Broken, near the Hartz mines, the vegetation of heath, myrtle, and all the species of moss, is so vigorous as to excite his astonishment; yet this mountain is ascertained to be upwards of 3000 feet above the level of the

sea. Heath and mosses are found on the top of the Andes and Mount Blanc.

Even though exposed to drought, the vegetation of these mosses, though checked, is not destroyed. Dillenius says, that he took a piece of moss from his herbary, which had been there for ten years: that this moss must, of course, have been completely dried; yet, when he left it in water for some days, it began to vegetate as if it had been newly taken from the earth.

Mosses, even when petrified at the roots, continue still to flourish on the surface. In like manner, though their roots, which sink deep in moss, seem to have decayed, the vegetation still advances over their ruins.

The seeds, too, of these plants float in the air: by this means they are universally diffused. When they reach any moist soil they fix upon it, and speedily rush up. The conferva is of this description. Dr Watson filled a tube with water, and sealed it hermetically at the top: that side which was next to the sun was speedily covered with a green film, the other side was not. Dr Priestly examined this, and found it to be a vegetable.

The rapidity with which this plant rushes up may be ascertained by a simple experiment. I have tried it myself within these few days. In a low level in this neighbourhood a ditch had been lately cut; ten days ago I made this ditch be stopped up so as to stem the water; to my surprise it is filled with con-

ferva, even on the 20th January. Some of the plants have already reached the surface in that short period, although the ditch be two feet deep.

It is unnecessary to point out the rapidity with which rushes, and reeds, and other aquatic plants grow.

The Doctor's first assertion, then, may be disputed, that moss produces few plants. If he mean annual plants, such as corn and wheat, &c. his assertion is well founded; or, if he mean only that mosses, when drained and laid dry, produce even few perennials, this may likewise be allowed.

But, in level mosses, where water is allowed to stagnate, the number of plants produced is great, and the luxuriance of their growth unequalled, even by the richest crop of wheat on the most fertile soil; and it is in such situations alone that moss is formed or renovated (as I shall shew in my third essay) to any considerable depth.

II. That the plants which grow on moss tend rapidly to decay, is an assertion which requires to be qualified.

In general, all vegetables tend rapidly to decay in certain circumstances. When exposed to the influences of the sun and air this is case. The alternation of moisture and drought, heat and cold, expedite this change; but it is not more rapid, even in these circumstances, in moss plants than other vegetables; on the contrary, many of these may

be preserved for a longer period than any other plants. All the varieties of heaths and mosses are of this description. It is not strictly true, therefore, that they tend rapidly to decay.

Far less can it be asserted, that these, or any other plants that flourish on moss, tend rapidly to decay when sunk in water, or shut up from the influences of the sun and air, as they are in moss.

Some of them are no doubt more susceptible of being preserved, even in this situation, than others.

I have already shewn, in the seventh section of this essay, that the hypnum, the aquatic grasses, rushes, and reeds, heath, and aquatic mosses, may be detected in a state of perfect preservation even in the deepest mosses, where they must have remained for ages.

The leaves and stems of these, which overtop the water, decay and drop annually; but the roots, and what remains of them under water, do not rapidly tend to decay; they often retain, for ages, their original organic form, otherwise they could not be discriminated in the lowest strata of the deepest mosses.

III. That all vegetable substances, when dead, decrease in bulk, so as not to occupy above the 100th part of the space they did, is an assertion which also requires qualification. If, by being dead, the Doctor means their ceasing to vegetate, the assertion is unfounded. The hypnum, the grasses, reeds, rushes, heath, and mosses detected deeply imbedded in peat, must have been dead for ages in this sense of the

word. It is inconceivable that they could continue to vegetate at the depth of 10, 20, or 30 feet of compact moss; yet these plants have not decreased in bulk a hundred fold; they have scarcely decreased at all; they occupy nearly the same space as they did when in a growing state; in form and size they can scarcely be distinguished from living plants of the same species.

If, on the other hand, the Doctor means by dead, their being disorganized, as they appear to exist in some mosses, even on this supposition, they must have occupied much more than 100th part of the space they did. Ligneous plants generally contain nearly one-fifth part of their bulk of carbon; that is almost an incorruptible substance; under water, or deeply imbedded in moss, it is entirely so.

Even those plants which are of a softer texture, and have no coriaceous nor ligneous fibres, contain much more than 100th part of their bulk of carbon.

IV. His assertion, that moss does not produce 100th part of the crop of a fertile soil, is very loose and incorrect.

Where moss is drained, its produce is indeed small; perhaps the Doctor does not under-rate it.

But in low wet mosses and lakes, where alone most grows to any perceptible degree, the crops it yields is great.

Some of the plants which flourish in such situations yield an annual produce, perhaps equal in bulk

to 20 crops of wheat. The ranunculus aquatilis, described by Rozier as rising from the bottom of a lake 18, 20, or 24 feet high, is of this kind. The produce of those moss plants which fill up the ditches in the peat moors of Craneburg, twice or thrice in one summer, are also of this description.

Besides, other considerations must be taken into the account. Most of the mosses, and many of the aquatics, which flourish on such soils, continue to vegetate all the year round; nay more, the vegetation of one, does not seem to check or retard that of the other, though closely interwoven together. Reeds and rushes may be seen on the surface of the water, fresh and full of vigour; while the conferva, the lemna, the byssus, potamogeton, &c. are equally vigorous below. Thus, innumerable crops of innumerable kinds are produced, not only annually, but some of them *continually*.

I need hardly mention, that as the temperature of the water in moss is almost always equable a few feet below the surface, and equal in all those regions where moss is found at that depth, that similar plants flourish in all these regions. In some, it would appear, they reach a greater size than others. The Marquis de Tourbillie mentions, that a species of rush grows in Bretagne, as high as a man on horseback. Dr King speaks of a coarse grass in the red bogs of Ireland, which rises as high as a man: the produce of either of these plants must be equal to the richest crop of wheat.

It would appear, from the foregoing facts, that the plants which promote the formation and renovation of moss, are possessed of the following qualities: They are, for the most part, extremely rapid in their growth; they do not rapidly decay; they are not much diminished in bulk; and, on all these and other accounts mentioned, they afford annually a much more abundant supply of vegetable matter than the most fertile soil. The rapidity with which moss is renovated in the pits dug in it, and the rapidity, too, with which it is formed in marshes and lakes, becomes less astonishing, because more easily accounted for.

There are other difficulties that may be accounted for upon the foregoing statement.

To obviate these shall be subject of

SECTION IX.

THE great variety of mosses; the immense depth of some of these; the situations in which they are found; and the arrangement of the different strata of moss in different countries, have been considered

by some as insurmountable difficulties, and unanswerable objections to the hypothesis I have supported. It appears to me, that these may all be accounted for.

I. The varieties of moss may be easily accounted for from the foregoing facts. These varieties are considerable; many attempts have been made to classify them; some have distinguished them by their different colours, others by their density, compactness, or weight; some by the prevailing plants of which they are composed, and others by the appearance they assume, or the qualities they are supposed to possess.

Degner describes three kinds of moss in Holland: He distinguishes these by their colour; the uppermost stratum as black and tenacious, the next redder, and the lowest redder still. Ribaucourt makes a similar distinction of colour in the French mosses, into white, brown, and black. Dr Leigh says, that the Lancashire mosses are either white, gray, or black; but they all agree, that there are many intermediate gradations of colour.

Girard discriminates the moss of the valley of the Somme by its density or compactness: He says, that the uppermost tier is loose and friable; that the roots and branches of reeds and rushes may be traced in it distinctly. The second is more homogenous and solid, but still the fibrous parts of vegetables appear, though entirely converted into moss; the woody peat

is undermost, and seems to consist of the trunks, branches, &c. of trees.

Degner likewise distinguishes the different kinds by their weight: One species, he says, is light and spongy, another is somewhat heavier, a third heavier still, and he speaks of some species specifically heavier than water.

Dr Walker, in describing the different kinds of moss, distinguishes them by the prevailing plants that seem to compose them, into wood-peat, flow-peat, heather-peat, gramineous-peat: he adds three more classes, the inch-peat, consumed-peat, and water-borne-peat.

Dr Anderson distinguishes moss into two kinds, living and dead: by the former, he means moss still in a growing state.

Poiret makes only two kinds of moss, fibrous and compact: by the former, he means all kinds of moss where the organization of the vegetable matter may be traced: under the latter class he includes all mosses which have undergone a complete disorganization.

It is of little importance which of these modes of classification be preferred. It appears to me, however, that the colour of moss is by no means a correct mode of distinguishing the different kinds; the shades and gradations of colour are so different, and so delicate, that it is difficult, if not impossible, to ascertain the exact line of distinction between the different species by this means. In describing these, however, it might be proper to attend to the colour.

The density, compactness, or comparative weight of peat, is likewise a very uncertain standard; these depend so much upon circumstances, upon the pressure to which the peat is subjected, and the degree of moisture, &c. &c. to which it is exposed, that it is impossible to make them a rule of discrimination.

The mode suggested by Dr Walker and others, of distinguishing peat by the plants that prevail in it, seems equally imperfect. Were this rule to be strictly followed out, (as it ought to be, if it ever be adopted), we might find out many hundred species of peat, as many as there are different species of plants in its composition: to attempt this mode of classification would only lead to confusion.

Dr Anderson's distinction, into living and dead, is still much more exceptionable; it is a distinction which does not exist; it originates either in an error of judgment, as to the nature of that substance, or in a misapplication of a vulgar distinction or metaphorical expression.

Were I to give a preference to any, I would prefer Poiret's distinction, into fibrous and compact: These two classes include all kinds, excepting perhaps wood-peat; and, in describing the varieties of moss, it seems to me unnecessary to be more minute.

Yet, upon the supposition that it is necessary to distinguish all the varieties of moss, we may easily account for this variety from the above view of their origin.

1. The different trees, as the oak, birch, fir, nay, the different parts of the tree, as the bark, leaves, and twigs, of which moss is composed, must constitute a difference in the appearance of that substance: the variety of aquatic plants which enter into its composition, must also occasion a variety of colour.

2. The age and consequent compression which mosses undergo at different depths, must also occasion a difference in their density, compactness, or weight.

3. The situation in which mosses lie may contribute to occasion a variety in their density. In low warm situations vegetation is rapid; in proportion to this rapidity of their growth, plants are less compact: hence in low sheltered spots wood and other plants are more soft and spongy; in high exposed situations, where vegetation is slow, they are more compact. We may expect the same variety in moss, according to the different situations in which it is found; hence in low vallies, moss is generally more porous; in high exposed situations, it is more compact.

4. The subsoil also may occasion a variety of colour and consistency in moss; salt, sulphur, or iron, may be dissolved in the waters of the subsoil; being diffused through the moss, they must occasion a difference in the colour, qualities, and consistency of it.

As the same metallic veins assume different appearances, and possess different qualities within a small space, it is not surprising that the same should happen in mosses.

5. Alluvion may also occasion a difference; sand or slime, or calcareous matter, may be carried down from the adjacent hills into mossy vallies; these, incorporating with the moss, may occasion a difference in colour, consistency, and weight.

But there is a more formidable objection to the foregoing hypothesis,—the immense depth of many of these mosses: to obviate this shall now be my object.

II. The depth of mosses may be accounted for. The whole objections of Degner and Dr Anderson resolve themselves into this: that moss is often found 20 or 30 feet deep: that the most abundant crop, on the most fertile soil, would not cover the earth, when fresh cut, half an inch deep: that, when rotten, it will not cover the earth one hundredth part of this; and therefore, if moss be formed of decayed vegetables, it must require many hundred thousand years to produce 20 feet deep of that substance.

We are now better prepared to meet this objection.

It cannot be denied that moss is found upwards of 20 feet deep. Girard says that in some places of the valley of the Somme it is 30; Degner says, that many of the Dutch mosses are as deep as this; De Luc says, that in some places Kedinger moor is 36 feet deep; and Mr Aiton says, that Moss Mulloch in Strathaven is upwards of 40. The French mosses, according to Ribaucourt, are from six inches to 20 feet deep at an average. The Dullatur bog in this parish is upwards of 50 feet deep. The engineer of

the great canal sounded it some years ago, and found it like a liquid pulp till he reached the sand at the above depth.

The following remarks may obviate this objection, and account for the immense depth of many mosses.

First, It is a fact attested by many, I believe it is denied by none, that all the deep mosses on the Continent of Europe, or the British Isles, lie either in low vallies, or at least on a level. I have never seen nor heard of any moss on a declivity that exceeded four feet in depth; on the contrary, all these mosses which lie on such declivities, or even on a dry bottom, are very shallow. The moors in Britain of this description, and all the dry mosses called *geest* on the Continent seldom exceed the half of this depth. In the adjacent vallies or levels alone is moss ever found of the immense depth above described. If these shallow and deep mosses be coeval in their origin, whence comes this vast difference? The most natural way of accounting for this is by alluvion.

Supposing the site of all these mosses to have been originally covered with wood; that this has laid the foundation of them; upon this supposition, alluvion must have had a powerful and continual operation, not only during all the period the forest stood, but all that in which the moss was forming. The annual crop of leaves, small seeds, and twigs, &c. together with the loose light earth formed by these on the declivities, must naturally have been carried

down to the vallies and level plains by the rains and winter floods; deposited there, they must have added to the depth of these low lying mosses, in the same proportion as they diminished that of those on the declivities. Upon the supposition that the forest stood only for one or two generations of it, say 500 or 1000 years, the quantity thus carried down to these levels, and the difference of depth that this must have occasioned, must be great indeed; and if this cause continued to operate even after the final ruin of the forest, and during all the period in which the moss was forming on its ruins, and operates still, that difference must still be greater. In the course of ages, we may expect that the whole moss formed on the declivities will eventually be washed down into the vallies. Alluvion alone, therefore, may account for the depth of many mosses, and the shallowness of others *.

* The effects of alluvion will be most easily conceived, by stating a case in point. The river Elbe was suffered to overflow a plain of nearly two leagues extent; in 23 years it formed an alluvial soil on this surface of two *feet deep*. This soil was of clay; but had the river, in its course, passed over a loose moss or lighter soil, it must have formed a much deeper stratum in a shorter period.

Or if it had lain in the course of one of those liquid running mosses which burst their barriers, and one of these had rested on this valley, a moss of immense depth might have been formed at once on the spot; and, unquestionably, many mosses now exist in such situations which originated elsewhere, and have floated down in the way above described.

Secondly, I have stated that, in these low levels, all kinds of aquatic plants rush up with rapidity: that, in 30 years, moss is renovated by this means to the depth of seven or ten feet. The conclusion is natural, that, by the same means, moss may have been formed with equal rapidity in such situations.

Whereas on dry grounds, or on declivities where no aquatics grow, and no other plants rush up with such rapidity and in such abundance, the materials for forming moss must be few, and its growth proportionably slow.

Thirdly, I have shewn that these aquatic plants are not diminished in bulk to the degree that Dr Anderson supposes: that they are detected in moss to the greatest depth, in their original organic form, and occupying the same space they did when in a growing state; for, though these and every other plant be diminished in size when they undergo decomposition in open air, this is not the case when sunk under water or buried in moss: even a crop of hay or wheat, in such a situation, is not diminished in bulk; and if annually sunk in water or moss, it would retain long its organic structure and original size. This is still more the case with aquatic plants; they are preserved, at least the sphagna, and all the other species of moss, for a much longer period.

I may add,

Fourthly, That one half of the size of the most compact moss consists of water. Take a cubic foot of such moss, and squeeze it till dry, it will not oc-

cupy one half of the space; so that even in a moss 40 feet deep, even supposing it to be compact, though none such exists, we have only to account for 20 feet, the other 20 consisting of water.

Fifthly, I have shewn, that many of the deepest mosses on the Continent, and in the British Isles, are in a semiliquid state; and I believe there is not to be found in the world any moss 20 feet deep of a compact and solid consistency; two-thirds, perhaps three-fourths, of such liquid mosses consist of water.

Sixthly, I have shewn that some of these, when drained, sink 10, 20, or more feet, which is a proof that the greatest proportion by far of such deep mosses is water.

Seventhly, I have shewn, that many of these semiliquid mosses burst their original bounds; by this means alone a moss of 20, 30, or 40, feet deep, may be lodged, in a *single day*, in a low valley where no moss formerly existed; or if moss was formed there before, this inundation of new matter must have added greatly to the depth. Accordingly, mosses are found of considerable depth on low level grounds, which were formed originally elsewhere, and afterwards floated down, in the manner above described.

Eightly, A moss 10 feet deep, if compact, contains as much vegetable matter as one 30 feet deep in a liquid state. They may, therefore, be coeval in their origin, and be the remains of the same plants: the difference of their depth may depend entirely on the above circumstances.

Thus, even upon Dr Anderson's own data, there is no need to account for moss 20 or 30 feet deep, as there is no instance I ever have heard of where moss is found nearly of that depth, excepting in low levels liable to the above operations of nature; all, or any of which, may account for the immense accumulation of that substance in such situations. Nor have we any cause to conclude with him, that it would require 900,000 years to form a moss 20 or 30 feet deep; on the contrary, if we take all the above considerations into the account, we may conclude with De Luc, that the rapidity with which moss is renovated, and may be formed in such situations, is obvious; and that the growth of moss, even 30 feet deep, does not lead us back to a remote æra. By alluvion and the rapid growth of aquatic plants, and especially by an accession of moisture, such an accumulation of liquid moss may be formed in a low level valley, in the course of a few ages; whereas on a declivity, by the operation of alluvion, the moss which was originally formed may be daily diminishing in depth; and on a dry bottom, where few aquatics can grow, and no plants rush up with rapidity, the growth of moss must be proportionally slow.

III. The situations in which moss is found may be accounted for on the foregoing hypothesis.

Moss is very generally diffused over the north of Europe. Guicciardini enumerates the different districts in Holland, Germany, and France, where it

abounds: He says, in general terms, that it is found at the mouths of all the rivers that empty themselves into the Baltic or German ocean. In Iceland and Russia it abounds, though it be little attended to, as they have a sufficiency of wood to supply them with fuel.

Ribaucourt says, there is scarcely a valley in France where moss is not to be found; that under the old forests, and even under many cultivated fields, it forms the subsoil.

Lamberville describes the mosses in France, and the names of the rivers on which it is found: He says, that it abounds most in the northern departments, especially on the Somme, and all its tributary streams; likewise along the rivers Esonne, Seine, Aine and Oise, Ecluse, Bressle, and the various streams that run into them.

In the East of France, he says, it is to be found in abundance; in Valois, on the rivers Mosselle, Meuse, &c.

In the south, it is less abundant, but it is found even there in the mountains: on the elevated plains of mount Jura; on mount Blanc; on the mountains of Cevennes, Pyrennees, and Auvergne, it is also found.

In the west of France, immense tracks of moss are to be found: on the right side of the Loire; on the banks of the Indie, Eure, and Iton, &c. it is also found in abundance.

It appears, too, that moss has been discovered in South America. Monardes describes a bituminous

earth dug at Peru, that possesses all the qualities of moss: He says, that they extract from it a liquid bitumen, which they use as a medicine; that they afterwards dry this earth and burn it: it lies in a marsh, and he says, that this marsh is bare of tree, shrub, or plant, of any kind. Mons. De Luc, in his first letter to me, mentions, that there are mosses on the mountains of Portugal and Spain: He says, he was informed of this by Professor Linck, who travelled through these countries, and paid attention to the peat grounds: He says, that, on the mountains where it is chiefly to be found, the peat is much like to that which abounds in the north of Europe; that it contains a great proportion of the scirpus cæspitosus; but that it is seldom found on low lands, excepting near the sea: This is of a different species; it is chiefly composed of the scirpus stolochænus, juncus acutus, and juncus maritimus, mixed with the roots of helodes and myrica gale, forming an indifferent peat, though tough. It is almost unnecessary for me to add, that peat is to be found in almost every valley of the British Isles.

But it is proper to observe, that it is sometimes found in the beds of rivers,—on a subsoil of bare rock,—under a bed of solid marl; and, even under the level of the sea.

De Luc takes notice of this as a difficulty which is not easily accounted for. He says, that there is no doubt moss is a vegetable substance; that we need only look to it to be convinced of this: That though

the compact moss at the bottom appear to be only a black earth, yet, even in it we may trace the roots and vestiges of the vegetables of which it is composed; and, if we pass by degrees to the surface, the organization of these vegetables becomes gradually more visible, till it appears distinct at last. The difficulties with regard to this substance, he adds, originate from two considerations: First, as to the cause of its formation; and, secondly, as to the situations in which it is found.

1. That it is sometimes found under the bed of rivers, stumbled him at first; but, as he had occasion to see it often in this situation, it awakened his curiosity, and, after a general survey of the whole coast, from the Elbe to the Meuse, he gives the following solution of this difficulty. He says, in general that one of two things must have happened in such cases, either that the river must have, at some period, changed its course, or that the moss found under its bed must have been moved, for it could never have been formed there. The following fact, which he mentions, removed all doubt upon this point: "On "the coast of the Ems the mosses were frequently "overflown by the river; they imbibed the water, "and swelled up, by this means, like a sponge. In "this state they often glided down as the river sub-"sided; there they remained in a semiliquid state. "An ingenious peasant seeing the cause of this, re-"solved to prevent it. He therefore cut off all com-"munication between the river and the moss, by

" means of a bank made of solid materials: piling " layer upon layer, as these sunk, they at last reach- " ed the bottom. From that time the moss was " never gorged up; what was within the bank re- " mained under the bed of the river, as formerly."

By this, or similar means, mosses may have glided down in a semiliquid state, and thus been lodged under the beds of rivers. Remaining there for ages, they may have been thus covered with a stratum of mud or clay; and thus alternate layers of moss and mud may have been formed at the mouths, or under the beds of rivers.

Accordingly, we find instances of this frequently occur along the coasts of the Baltic Sea and German Ocean, especially at the mouths of rivers. In boring to the depth of many feet, alternate layers of moss and clay and sand and slime are found. This can only be accounted for on the above hypothesis.

2. Mosses are sometimes found on a subsoil of bare solid rock. This is stated by Dr Anderson, with his wonted confidence, as an insurmountable objection against the hypothesis that is laid down in my first essay.—His words are, " What I conceive to be an " incontestible proof that moss may abound where " no wood ever existed, is, that the soil on the hilly " parts of South Uist, consisted entirely of moss, " without one particle of earth intervening between " it and the rock; and that rock was everywhere " a bed of solid granite, without a fissure in almost " any part of it, so that, wherever it formed a cavity,

"great or small, it was perfectly water-tight, like a "bason. I was at great pains to examine the hill "lakes which fell in my way, and these are nume- "rous, and I found no exception to this rule. In "these circumstances, I think it inconceivable, that "even wood of any kind could have existed before "the moss began to be formed."

He adds, "In the island of Lewis there is an ex- "tensive plain of about 30 miles in length, which "reaches nearly from sea to sea, and which is en- "tirely covered with moss. Its surface is very little "elevated above the level of the sea; and, in every "respect, its situation is so unfavourable for the pro- "duction of wood, as to render it extremely probable "none could ever have grown there."

In reply to this, I observe, that it is even conceivable that trees may have existed on the former of these islands. It is well known, that even on a bare rock, especially where there is a level or hollow, such as the Doctor describes in the island of Uist, a variety of moss plants will grow. As they accumulate, the moisture rises with them; they retain it like a sponge; and thus they form a soil fit for the growth of trees. De Luc mentions, that he has seen a detached block of stone covered with moss plants, upwards of a foot thick, and on this a large tree, growing as on its proper soil. That the island of Uist may have, at one time, been covered with wood, though originally a bare rock, is not inconceivable;

and that moss may have been formed on it, by a succession of aquatic plants, is equally conceivable.

As to the island of Lewis, it is certain that a forest once existed upon it. Though now destitute of growing timber, as the Doctor asserts, Mr Headrick says there are large trunks of oak, elder, birch, and especially of Scots fir, found in its extensive mosses. In the year 1800, that gentleman observed a considerable number of small stunted firs on the higher parts of that island, the remains of the antient and extensive fir woods.

If trees may have existed in Lewis, and even in Uist, and if aquatic plants may have flourished on both, as a favourable soil, there is no difficulty in conceiving how mosses may have been formed on these islands; nor is it unreasonable to suppose, that the same ligneous and aquatic plants which promote the growth of moss elsewhere, may have given origin to it there.

Even on the supposition that there is not one trunk or the smallest vestige of a tree in the above islands, or in the mosses they contain, still the origin of these mosses may be accounted for on the above hypotheses. Mosses and other aquatic plants may have furnished the materials; and the situation of these islands seems to be peculiarly favourable for the growth of these.

3. Mosses are found on the tops of high mountains, where a tree cannot now be made to strike root, or grow at all. Dr Anderson likewise takes notice of this: He says, that most of the hills on the west coast

of Scotland and the Hebrides are covered with moss, in situations so exposed to the winds and sea spray, that no wood of any kind has been seen to grow on such exposures. He might have added, that moss is found likewise on the Alps and Appenines, though now covered with perpetual snow; that they are found on the high mountains of Blocksburg, and even in the cold region of Iceland, in all which situations no tree nor shrub can now be seen*.

Yet, in all these situations, trees have been dug up out of these mosses; and in all of them aquatic plants have been found still in a growing state, even under the snow.

Whatever change of climate these mountains may have undergone, it is certain that the same ligneous and aquatic plants that form moss elsewhere are to be found there; so that these situations furnish the same materials, and (as I shall shew in the third essay), possesses the same advantages requisite to the formation of moss, as others where that substance abounds.

4. Moss is sometimes found in the bottom of the sea and of salt lakes. In such situations it could not be formed; how then can we account for the formation of it by ligneous or aquatic plants in such situations? Dr Anderson likewise takes notice of this:

* Villars mentions, that, in the canton of Oiseau, in the department of Isire, turf is found 7 or 8000 feet above the level of the sea, and 3000 above the level where trees now grow.

He says that, in the harbour of Oban, peat moss is found at the bottom of the sea, at the depth of 20 fathoms. All along the Dutch coast, and the shores of the Baltic Sea, the same phenomenon may be observed, &c. &c.

Yet even this may be accounted for on two hypotheses; either that the moss on the Continent has been carried by the current of the rivers into the sea, as often takes place with that particular species of peat called *darry* in Holland; or, that an inundation of the sea may have overwhelmed a part of the Continent where moss was already formed. Instances of both these events are recorded; and either of them may account for this phenomenon. I have mentioned some of these in my first essay, p. 52, 53; I shall name a few more.

The Baltic Sea, for instance, has made great inroads on Pomerania; it has overwhelmed in the deep the famous port of Vineto: the Norwegian Sea has formed many islands in that country by inundations: the German Ocean has buried under its waves the ancient Roman citadel, near to Call, which was formerly a sea-port town. A similar inundation separated Dodrecht from the mainland in 1421. In 1446, upwards of 10,000 souls were overwhelmed by an inundation in the territory of Dodrecht, and more than 100,000 in Friezland and Zealand.

That mosses may have been formed in these ill-fated districts before they were overwhelmed with the deep, is highly probable. But there are instances re-

corded in which this certainly was the case; and the dates of these are known: In the year 1717, the marsh of Wishhssen was buried in the deep, and the ruins of the ancient village may yet be seen under the waters. Fluiessen Meer was a wood in the year 489, when it was overwhelmed by the ocean. In 1222, the Zuyder Sea had no existence; it was formed at that period; till then it was a gulf. Yet it was partly inhabited, and contained a number of villages: A high sea, accompanied with an impetuous storm, overwhelmed all in the deep.

By similar inroads of the ocean, forests and mosses already formed may have been overwhelmed in different kingdoms; on the coast of Lincoln we have a striking example of this.

The mosses of Merionethshire, in Wales, which extend along the shore to Tomyn, reaching into the sea to an unknown extent, have probably undergone a similar fate.

5. Moss is often found under a deep bed of sand. This can easily be accounted for: On the Continent the dry hills called *duyns* consist of moving sands; these are often tossed by the winds, and thus flying about in all directions may have overrun these mosses. On the sea coast, where instances of this are often seen, they can be accounted for from similar causes; the winds and waves combine to move these sands: by their united operation, mosses may be buried deep in sand.

6. Moss is sometimes found under a bed of solid marl. Duhamel, junior, mentions an instance of this near the forest of Brotonne. It is 11 feet thick under the marl; it extends to upwards of 400 acres. This may be accounted for: It is certain that calcareous earth is often held in solution in water; the numberless petrifying springs which exist in all parts of the world are a sufficient proof of this; it were superfluous to enumerate these.

In general, I observe, that in Derbyshire, Yorkshire, Somersetshire, &c. and most of the counties in England, they abound.

These uniformly deposit the calcareous earth where-ever they are allowed to stagnate. Some plants seem to have a more powerful attraction to it than others, or being more porous, they are more retentive of it. Mosses and liverworts are thereby petrified, while primroses and geraniums, which grow on the same spot, escape. Almost every species of vegetable, however, has been found in a petrified state; and bones of animals and other substances have submitted to the same change.

Some waters are so replete with this matter, that they speedily clog up the channels in which they run. An instance of this is mentioned at High Littleton, in the county of Somerset: A pipe had been constructed of an elm-tree, to convey the waters from a coal pit; though this was placed in a perpendicular direction in 1766, it was so obstructed by the sparry incrustation formed in the cavity, that it was no long-

er useful. In less than three years the miners were obliged to take it up. This incrustation was somewhat softer than marble, but harder than alabaster.

In Italy this process goes on in a very extended scale. The beds and banks of many rivers in that kingdom, but especially the basons in which the waters stagnate, are frequently filled up by this means.

Now, if any rill or river, impregnated with calcareous earth, happened in its course to run over a plane in which moss was formed, it is obvious that it must leave a sediment; this sediment being calcareous, would speedily be consolidated into marl or lime.

An instance of this I shall name. Mercatus says, that the river Velino, passing in its course the town of Reate, belonging to the Umbri, spread over the widely extended marshes, and formed the lake Velino. Overcoming its lofty banks, its waters were precipitated over a precipice; but the stony sediment it left so considerably filled up this cataract, as to shut up the waters, threatening to swallow up the adjacent fields of the Reatines. If the cataract was thus contracted, and at last shut up by the subsidence of calcareous matter, it is reasonable to suppose, that these extended marshes would be covered with a thick stratum of it; accordingly, it is said, similar inconveniencies were felt by the inhabitants. Every crevice was filled up with this matter, and all the loose soil over which these waters run was rendered

stony and barren, though formerly allotted for pasturage and corn.

Thus a stratum of calcareous earth may have been formed over a valley which was formerly a morass; and thus we may account for moss being sometimes found under a stratum of marl, or even of limestone.

It is known, too, that shells and calcareous matter are often found incorporated with the moss itself; these probably owe their origin to the shell-fish which existed in the marsh before it was converted into moss. If this marsh was occasionally overflowed by the sea, shell fish peculiar to that element may thus be expected. If the waters were fresh, other species may be looked for.

That innumerable shell fish may be found in many marshes is certain. It even appears probable, that they may exist and propagate after the marsh is partly converted into moss.

The Earl of Cromarty mentions an instance which renders this supposition less improbable. He says, that in a moss near the town of Elgin in Murray, though no river or water communicates with the moss, yet, for three or four feet deep, there are little shell fish resembling oysters, with living fish in them, in great quantities, though no such fish are found in the adjacent rivers, nor even in the water-pits in the moss, but only in the solid substance of the moss itself.

Dr Darwin justly considers this as a very curious fact. He thinks that it may account for the shells sometimes found on the surface of coal mines, and in the clay that accompanies these; and likewise for the stratum of shells which sometimes exists over iron ore.

At all events, it accounts for the shells and marl that is sometimes found incorporated with moss. It would be proper to search such mosses in order to discover what is the food of these fish. It is very improbable that the moss can furnish them any nourishment; and it appears that they do not live on the moss water, for in the water-pits dug in the moss no fish are found; and I shall have occasion to shew, that both moss and moss water are unfavourable to animal life; that few animals of any species exist in either, at least after the moss is formed. Perhaps the moss described by the ingenious Earl may have been, at that period, only a morass; and probably no living fish now exist in it. The reader who lives on the spot may examine this.

It is probable that the small shell-fish found in moss were either washed down into the level where such mosses now exist, or that they were formed there before, or during the time that the moss itself was growing. It is unnecessary to say that many species of shell fish exist in marshes and lakes; and it is well known, that water impregnated with calcareous earth, or carbonic acid, when it subsides in

such situations, consolidates these into marl, by enveloping and cementing them together.

Accordingly, marl found in such low levels always abounds with the same shell fish which are to be found in the adjacent heights. This is particularly the case in the Lake Constance, and along the banks of the Rhine, where shells are buried. Mr Coupe observes, that the same is the case at Corbeil, Hiere, St Thebant, Lagny, Chille, Montfermeil, Gagny, Montmorency, &c. &c.

Where marl is therefore found, either under moss or incorporated with it, the probability is, that it is formed of the shell-fish either washed down from the adjacent height, or of such as existed in that situation before the moss was formed, or while it was only a marsh or lake: it is not surprising, therefore, that it should be found above or below the moss, or incorporated with it.

7. Sometimes moss lies in alternate layers of coal. Du Hamel, junior, mentions an instance of this: He says that, in Provence, sometimes a foot or two of moss is found between two of coal. From the account he gives of that moss, it seems rather to resemble Bovey coal.

Beroldinguen mentions a curious case in Messner, one of the mountains of Hesse. The surturbrand was found there below a bed of basalt; yet the fibrous form and annular rings of the wood were distinct: Nay some logs were found cut into uniform lengths, bearing the marks of the hatchet and saw. He sup-

poses that this had been once a forest; that it had been overwhelmed by a volcanic eruption; that the coal and surturbrand were formed by this means.

I need scarcely mention, that,

8. Moss is sometimes found in Friezland and elsewhere, without any trees or evidences of ligneous plants. This is easily accounted for: Many mosses may have been formed entirely of aquatics; others may be water-borne. In either case, they must contain few or no trees. In the former case, none can be expected; in the latter, if the moss was in a fluid state, the trees, by their specific gravity, may have sunk in it before it flowed; the liquid loose moss alone being carried along the stream, no traces of its ligneous origin can be expected in it, after it has been deposited on its new base.

9. Dr Anderson takes notice of another fact, which he thinks does not quadrate with the idea that foggy peat consists of the sphagnum, &c. &c. "In most "mosses, (he observes,) there are found different strata "of different qualities. These are universally disposed "in different layers, so that the black peat sometimes "lies above the foggy peat, and *vice versa*. Now, if "it be supposed that the foggy is produced by the "sphagnum, &c. it must invariably have been found "on the surface only, and could never have been "formed below the good black peat."

In reply to this I observe, that it appears that it is only in Holland where this is the case. Degner says, that the best peat there is generally uppermost; that it is of a yellow brown colour; the spongy reedy

turf found deep in the bottom is not good fuel. In Groningen, he says, that the spongy peat is found on the surface, and the best below it.

In the mosses in Britain and on the Continent this is generally the case. De Luc states, indeed, that in the mosses of Bremen, the good and bad is sometimes found in alternate layers. But Mr Findorf gives a very plausible account of this: That, in dry summers, the ligneous plants prevail; in wet, the aquatic. That the alternate layers of black hard peat, the residuum of ligneous plants, and soft spongy peat, the residuum of aquatic mosses, &c. may thus be accounted for.

Nor is it unaccountable that, in the mosses of Holland, the fibrous spongy peat should form the substratum. These mosses all lie on a low level, little above that of the sea. In one stage of their formation, these may have been marshes. At that period reeds and rushes, and other aquatic plants, such as the sphagnum, may have flourished; thus materials may have been formed for the fibrous spongy peat called *darry*. At a future period, these mosses may have been overflown and converted into lakes. In this stage of their formation, the conferva, lemna, byssus, and other soft tender aquatics, may have flourished; these, by their rapid growth, may have furnished materials for the more compact and less fibrous peat on the surface.

The account that Degner gives of the stratification of the Dutch mosses corresponds with this.

" The surface of many of them is covered with " grass. After digging one or two feet through this, " the turf is laid open ; the first tier of this is black- " ish red, very tenacious ; it is, however, soft and " pulpy, and yields the best fuel. It is only about " two feet deep. The second stratum is somewhat " redder, equally tenacious, but still full of fibres. " The lowest stratum is much redder still ; it is so " fibrous and spongy, that it appears like rotten " wood : this is the worst fuel. At the depth of " nine or ten feet, a sandy slime is laid open ; this is " quite useless as a fuel."

If the reader consult what is stated in p. 128 and 129 of this essay, he will see how the above stratification of moss may be accounted for.

10. It has been questioned by some, and denied by others, that there are any mosses on the Continent of America.

Guicciardini says, that it is not known whether Asia, Africa, or America, contain any mosses, as no search has been made. Degner and Dr Anderson deny that there are any in these regions. The latter says that he has been assured, from very good authority, that there is not to be found on the whole continent of America a single particle of real and genuine peat moss. The former argues upon this as a fact : " If," says he, " forests are converted into moss, the " greatest part of Moscovy, Tartary, America, and " other woody uncultivated regions would have, ere

"now, undergone this change, which is not the "case."

To this I reply, 1*st*, That in woody regions, moss is of little value; it is never in request as a fuel, as the abundance of wood supplies its place. No efforts are made to search for it as a soil or a manure. The former can be procured in abundance; the latter is less requisite. Mosses, therefore, may exist in these regions, though no notice be taken of them.

2. Accordingly, in Russia they abound; many marshes and valleys in that empire are filled with it. This I am assured of from unquestionable authority.

Tooke, in his View of the Russian Empire, says, that in Siberia, there are abundance of morasses of different magnitudes. Towards the shores of the Frozen Ocean, for several hundred versts in width, is one prodigious watery morass, grown over with moss, and destitute of wood.

In the interior of the country are many smaller: He specifies four different kinds: 1. Low watery land; 2. Swamps which yield turf; 3. Bottomless morasses, which appear to be lakes overgrown; 4. Moss morasses, the deep and useless moss of which will permit neither grass nor shrub to grow.

3. In South America, at least on the Peruvian mountains, it has been discovered. I have also been informed by a gentleman who lived thirty years on the banks of the Mississippi, and had occasionally visited all the United States, that moss is frequently found in the vallies. He mentioned, that it is generally co-

vered with a green surface which conceals it from view; but below this many feet of moss is often found. He said that the skeleton of the bergamot in the possession of Mr Peel, was dug out of moss.

Till it be ascertained beyond a doubt that there is not to be found a particle of genuine peat in these regions, it would be superfluous to offer any reply to this objection, or to attempt to obviate this difficulty.

Having attempted to shew that moss is renovated, and pointed out the circumstances and time requisite, and the aquatic plants which promote this process; having also endeavoured to prove, that the same plants have contributed to the original formation of moss in marshes and lakes, and that many lakes and marshes have undergone this change; having likewise shewn that these aquatic plants may still be traced in their original organic form in many mosses, and pointed out a few of the distinguishing qualities of these plants, it only remains for me to shew to what General Conclusions this naturally leads us.

SECTION X.

GENERAL CONCLUSIONS.

I. The *first* general conclusion is, that moss is certainly of vegetable origin.

Some species may appear, at first sight, of doubtful origin; but the greatest part is obviously a congeries of vegetables. To be convinced of this, we need only to look at that substance. The organic structure of the very plants of which it is composed may be traced from the surface to the greatest depth. As might be expected, we may mark a progressive gradation from a state of perfect organization to an evanescent state, where this organization is totally destroyed.

In this last stage the origin of moss may appear dubious; and if it were only found in this state, it might be difficult to decide whether it was of vegetable or mineral origin; but, as the above gradation can easily be traced in every moss, it is fair and reasonable to explain the doubtful by the decisive, and the obscure by the luminous; and as most of mosses on the surface are clearly composed of a mass of vegetables, and as all moss, in all these gradations, is possessed of similar qualities, the conclusion is natural and irresistible, that they may all be traced to the same source.

Degner accordingly observes, that all moss, even the most compact, when diluted in water, and reduced to powder, if examined by the microscope, seems to consist of nothing but a congeries of leaves, branches, and roots of vegetables. He adds, that when the powder of peat is dried, it presents the same appearance. He therefore concludes, that it

is impossible to doubt that it is a congéries of vegetable matter.

II. *Secondly*, We may conclude that all moss is either composed of ligneous or aquatic plants; and that these furnish abundant materials for the purpose.

The leaves, the seeds, the twigs, the bark, and rind, with the roots, trunks, and branches of the former, lay the foundation of most mosses; over this the latter raises the superstructure.

On this supposition, it may be expected that ligneous plants would chiefly compose the lower strata; and that aquatics would abound most in the higher. This is accordingly the case wherever moss exists; even in those which seem chiefly to be composed of aquatics, and are still in a semiliquid state, wood is found at the depth of 10, 20, or 30 feet. Nine-tenths of the mosses of Europe are of this description.

No doubt, therefore, can remain as to the materials of which these are composed. The only point that may seem dubious is, whether these materials are sufficient for the purpose.

To remove all doubt on this particular, I shall give a rough calculation of the accumulation of these materials. To some this may appear fanciful. I may be condemned for building castles in the air. Of this the impartial public must judge; by their decision I am willing to stand or fall.

Supposing the forest which furnished the first materials for the formation of moss had stood only 500 years before it fell into ruins, the following calculation will be found moderate.

1. The leaves annually tossed by the winds, and washed down by the rains into the hollows of the woods, may have furnished, in that period, three feet of materials.

2. The seeds and twigs that dropped annually one foot.

3. The bark and rind, at the final ruin of the forest, six inches.

4. The white wood six inches.

5. The carbon of the wood, supposing it to be bituminated, nine inches.

Even on the supposition that this forest only stood one generation, five feet nine inches of materials are thus furnished: if it survived two or three generations, the account must be doubled or trebled, call it only ten feet, in round numbers.

Thus we have materials sufficient for a moss of considerable depth. But this is only the foundation of the building; over this an almost endless variety of aquatics rush up with rapidity. Supposing these only to add, in a century, three feet more materials, total 13 feet. By the continued operation of alluvion, and the other operations I have mentioned in the ninth section of this essay, and especially by an accumulation of moisture, equal in all moss to the half of its materials, and in many to the double of

them, we may safely suppose the above account to be doubled, say 26 feet.

Thus abundant materials are provided.

III. *Thirdly*, From the above account we may conclude, that many regions, now covered deep with moss, were at one period arable lands, at another forests, at a third lakes.

We may still trace these changes, and mark their progress in many mosses. For instance,

1. Under some mosses the marks of the plough, and even ears of corn and other grain, with various utensils of husbandry, have been found.

These are clear evidences that, at one period, the above surface was a ploughed field.

2. In these ridges a vast variety of trees are found, some standing erect, others fallen prostrate, but all with their roots fixed in this subsoil of arable land. This is a proof that, at a second and subsequent period, the surface was covered with a forest.

3. These trees are sometimes found immersed in moss of a semiliquid state, to the depth of 10, 20, or 30 feet; and aquatic plants, such as flourish in water, may be still traced through all its depth. Nothing can be a clearer proof than that this, at a third and subsequent period, has been a lake.

And, in this stage, some lakes are still found. Lough Neagh is an instance of this. Mr Smith, in his account of it, mentions, that part of this loch was formerly a forest: that this is the common tra-

dition among the inhabitants of that district: that it is probable, for much wood is found in it: that this wood is sunk in a kind of pulpy moss called mire, black at the bottom of the lake. If so, it will naturally be asked, why the whole loch has not been converted into moss? It is impossible for me to assign the reason. Perhaps the great extent of the surface, and the agitation of the waters by the winds, may be unfavourable for the growth of those aquatic plants which contribute to form moss; or, perhaps, the petrifying quality of the waters may be unfavourable for this purpose. If the aquatic plants above described grow in any sheltered bays of this loch, and if they are there accumulated, they may ultimately be converted into moss. This I mention merely to excite the attention of the intelligent part of the inhabitants of that district to the subject.

4. It is certain that, in other places, many lakes have been, by the above means, filled up and converted into mosses.

5. And it is equally certain that, at a subsequent period, these mosses, by consolidation, may have been converted into meadows, and afterwards into rich arable lands. Most of the fertile plains along the banks of rivers, in the north of Europe, are of this description; they, of course, generally lie on a subsoil of moss.

So that it is probable that many of these have, in the course of ages, undergone all the above changes, from arable lands to forests, from forests to lakes,

from lakes to mosses, from mosses to meadows, and from meadows to their original state of arable land; I call it their original state; but I think it probable that, before they were first cleared and cultivated, they were originally covered with wood.

It is natural to suppose, that many low levels, covered with wood, have been converted into morasses. The trees, by falling into decay, and stemming the course of rivers, may have occasioned such a stagnation of water as to cause this change. It is equally natural to suppose, that such low levels may have been converted into deep lakes. The mouths of rivers may have been so stemmed, by accidents such as I have described, p. 51 and 52 of my first essay, as to raise the waters in the valley to a level above all the plants and trees that originally sprung up and flourished in it. If this valley was of small extent, and the lake formed in it favourable for the growth of aquatic plants, the whole waters may have been first covered over with a matting of these. By consolidation, and the continual accession of vegetable matter, the whole lake may have thus been converted into a moss.

All those mosses which are deep, and contain trees, some standing erect and others prostrate on the original subsoil, and especially those which contain a rushy, reedy peat above these trees, and a black compact moss above this, seem to me to have undergone these changes; and the vast extent of mosses of this description over Europe, probably origi-

nated in this way. It were superfluous to enumerate instances of this. I shall only specify two ; the first is Low Modena, which seems to have undergone all these changes ; the second is the bog of Monela in Ireland, which seems to have been subjected to a similar succession. Ramazini describes the former; Carr, in his Stranger in Ireland, delineates the latter.

The stratification of the vicinity of Modena is somewhat singular. " The surface of the valley is " now a rich arable field. At the depth of 14 feet " below this, it is said that the rubbish and ruins of " an ancient city were discovered. Paved streets, and " pieces of mosaic work were found at this depth: " below this the earth is solid, and seems not to have " been moved : lower down is a loose moist soil, mix-" ed with vegetables ; and, at the depth of 26 feet, " entire trees, such as filberts, with nuts, and a great " quantity of branches and leaves have been dug up. " At 28 feet deep a stratum of soft chalk, mixed " with shells, was discovered. This stratum is 11 " feet thick. Below this, at the depth of 40 or 50 " feet, there is to be found the soil of a low marshy " country, full of sedge, reeds, shrubs, roots of " trees, nuts, ears of corn, leaves of trees, branches, " and boughs." He even describes the species of wood. He says, that oak, elm, walnut, ash, and willow may be distinguished. " Some of these trees " are broken down, othere stand still upright as they " grew. Among these are found old Roman coins, " marbles, stones squared and cut by the hands of

"men. Each tree is found on the soil most adapted "to its production. The fir roots are fastened in the "sand, the oak in the clay."

The whole of this valley, he says, was a lake in the reign of Julius Cæsar. The surface is now drained and consolidated, and converted into arable land.

It seems obvious to me, that this valley has undergone all the changes above described; at one period it has probably been arable land; hence the ears of corn, &c. which have been discovered: subsequent to this it seems to have been overgrown with wood; hence the trunks and roots of trees: this wood seems afterwards to have been converted into a morass; hence the sedges and reeds, &c. which are found: this morass seems to have been after this consolidated by alluvion; hence the stratum of soft chalk and shells.

Above this, another generation of a forest seems to have sprung up; hence the other tier of branches and leaves of trees. This second generation seems to have undergone the same fate with the first; the moist soil mixed with vegetables above it, seems to be the remains of the marshy plants that must have sprung up after this forest was also converted into a morass.

This morass seems again to have been consolidated, probably by alluvion; hence the stratum of solid earth: on this the city seems to have been built; hence the paved streets, &c.: the 14 feet above this seems to have been formed after the city was overwhelmed with some inundation.

Whether the lake that existed on the spot at the age of Julius Cæsar was thus formed, it is impossible to decide. If so, however, the 14 feet of solid soil above this city, must have been formed since that period.

That many low lying vallies in different parts of the world have undergone similar changes, is not only probable but certain. The mosses of Ireland exhibit similar proofs of this: in digging deep into these, recumbent forests upon forests are found, with a layer of earth between.

This leads me to notice the other instance mentioned by Carr, in his Stranger in Ireland: He says, "that the bog of Monela is not far from the bog of "Allan: stumps of trees are still visible on the surface of the former; under these lies a stratum of "turf 10 or 15 feet deep: under this, a tier of "prostrate tress is discovered; beneath these another "stratum of earth is found of considerable depth: "and below this a great number of stumps of trees "are found, standing erect as they grew. Thus, "there is a succession of three distinct forests lying "in ruins, one above the other."

He says, "Some of these mosses have been perforated deeper than 50 feet: at the bottom of "many of them, he observes, arable land has been "discovered, bearing the marks of the plough, and "formed into regular ridges."

These fragments of the natural history of mosses, may furnish us with some faint ideas of their origin

and formation. If we were to discover the hulk of a ship, or even a few beams, sunk in the ocean, we would be at no loss to say, that these were the remains of a wreck. The size of these beams might easily lead us to distinguish between the wreck of a frigate and a first-rate man of war. The state of preservation in which these are found, might give us some idea of the period at which the wreck happened.

It is precisely so in examining the history and origin of peat mosses. The ruined forests found in these leave us no doubt that they have been partly formed of the wrecks of these. The size and species of trees lead us to conclude what must have been the age of the forest when it fell into ruins. The state of preservation of these trees, and the depth of soil formed above them, may give us some faint idea of the period at which they fell. The remains of aquatic plants, reeds, and rushes, &c. found above them, give us likewise an idea of the cause of their ruin; and, the stratification of the soil, exhibits a view of the changes it has undergone in the lapse of ages.

IV. It is obvious, from the above statement, that moss, in favourable circumstances, is renovated with rapidity; it seems reasonable to conclude,

Fourthly, That it may have been originally formed with equal rapidity in similar circumstances.

The quantity of materials which a fallen forest may yield, has been calculated. The rapidity with which

aquatic plants may contribute to its subsequent increase, may be conceived from the following considerations:

First, These plants are generally very rapid in their growth; this point is fully established in the foregoing pages.

Secondly, Most of them vegetate, and even flourish, in the coldest climates, and some of them continue to grow all the year round.

Thirdly, While they are rapid in their growth, they are generally slow in decay, especially when immersed in water.

Fourthly, In this medium they are not diminished in bulk, but occupy nearly the same space that they did while in a growing state.

In place, therefore, of yielding only 100th part of the vegetable matter which a fertile soil produces, they must contribute more than the richest crop of wheat on the most fertile soil.

Mr De Luc says, that this is the case even on the lofty mountains of Blocksberg. His words are, "the "plants which continue to grow by the moisture of "the air above, and of the moss below, heap up "*twenty times* more materials annually than an or-"dinary soil produces."

From all these considerations combined, it appears reasonable to conclude, that moss may be formed with great rapidity in such situations.

Lastly, We may conclude, that (in place of requiring 900,000 years to form a moss 20 feet deep), the

deepest mosses which exist may have been formed, by the above natural process, in a much shorter period; and that the origin of these does not lead us back to a very remote æra.

Hitherto I have only endeavoured to ascertain what are the materials of which moss is composed, and to shew how these have been accumulated together. Were I to stop here, my object could not be attained; and, as all moss contains certain chemical qualities, different from recent vegetables of the above description, some doubts might still remain as to the origin of that singular substance.

It remains for me to shew, that these materials must naturally undergo certain chemical changes in the lapse of time; to point out precisely what these changes are; to ascertain the causes of these changes, and the consequences of them; and to point out the precise state in which these materials now appear; in other words, to shew what moss really is;—

This I reserve as the subject of the third and fourth essay.

I cannot, however, take leave of the public at this time, without pleading some apology; the length of these essays, and the loose style in which they appear, require this.

My great object has been to collect facts; and every fact that seemed to elucidate the subject, I have stated fully: this is the cause why these essays have swelled to such a size, and why they appear to be so

prolix. I cannot but flatter myself, that they may be valuable on account of this collection of facts, and on this account alone. As to the conclusions I have drawn from these, and the hypothesis I have stated, they may be false and ill founded. Of this the impartial public will now judge; and I leave them at full liberty to controvert every conclusion, and tear up every hypothesis root and branch: in place of feeling mortification, I shall rejoice to see the subject elucidated by an abler pen. All the favour I ask, (and I solicit it with importunity), is this, that if I have misrepresented any fact, or overlooked any thing of importance, they will be pleased to signify this without delay. It is on this account that I have resolved to publish these essays first, as they lay the foundation of my work; and before the subsequent part of it be published, I expect to receive much information, and many strictures.

As to the style, I acknowledge it is loose and desultory. In this shape it is not fit to meet the eye of the judicious critic; it claims the chastisement of the public; and all the apology I can plead, is, that elegance of style has not been my aim: perspicuity and precision is the utmost height of my ambition.

George Ramsay & Co. Printers,
Edinburgh, 1807.

ERRATA.

P. 20. l. 9. for S*o*mana read S*e*mana
P. 77. l. 8. for Woodhead, &c. *&c.* read *and*
P. 116. l. 26. for may distinguished, read may *be*
P. 121, *Note, foot,* for trans*ci*de, read trans*u*de
P. 140. l. 9. for autum*m*, read autum*n*.

ADVERTISEMENT.

Speedily will be Published,

ESSAY III.

ON THE CHANGES AND COMBINATIONS WHICH VEGETABLE MATTER UNDERGOES WHEN CONVERTED INTO MOSS.

ESSAY IV.

ON THE SIMPLE AND COMPOUND SUBSTANCES WHICH MAY BE EXPECTED, AND ARE REALLY FOUND IN MOSS.

ESSAY V.

ON THE DISTINGUISHING QUALITIES OF PEAT MOSS, AND THE CAUSES OF THEM.

ESSAY III.

ESSAY III.

ON

THE CHANGES AND COMBINATIONS

BY WHICH

VEGETABLE MATTER IS CONVERTED

INTO

PEAT MOSS.

In the two Essays already published, an attempt has been made to ascertain the materials of which peat-moss is composed. That it is of vegetable origin, and consists of a congeries of ligneous and aquatic plants, or of both, can scarcely be doubted.

These materials, however, must have undergone certain changes in the lapse of time. It is, therefore, natural to expect, that they must differ essentially from the recent state in which they were deposited. To point out these changes, and the causes and consequences of them, and to ascertain the state in which these materials are now found; in other words, to shew what peat-moss is, shall be the object of this essay.

With this view it may be proper to shew,

I. What is requisite to the formation of moss from vegetable matter, and in what medium it is accomplished:

II. The changes and combinations that take place during that process:

III. The agents which cooperate to effect these changes and combinations:

IV. The consequences that result from them; and,

V. The general conclusions which may be deduced from this view of the subject.

This subject is intricate, and must involve discussions which may be of very doubtful issue, as they are new. "Hitherto, says Broingiart, we have no "certain data on the formation of peat-moss. We "cannot yet ascertain why that substance is formed "and renovated in certain marshes, while in others, "equally filled with aquatic vegetables, no such pro-"cess goes on."

To ascertain such data is an arduous task. None but an accurate chemist can ever accomplish it. The author of these essays can lay no claim to such a qualification*. He labours under other disadvantages. Living in a retired corner; shut out from many sources of information; secluded from the society of literary men; and employed in the arduous and delightful duties of an important public office,

* He deeply regrets this defect. He has done his utmost to supply it, by consulting the best authors on the subject. But he is abundantly sensible that this is not sufficient.

he can devote only the few leisure hours of recreation to such researches.

He pleads not this as an apology for any chemical blunders into which he may have fallen. These he will rejoice to see rectified. To elucidate such a subject completely he has no pretensions. That is a task reserved for a Hatchet or a Davy. To collect and arrange the leading facts which may ultimately be of use for this purpose, is all his aim. And if the hints now thrown out, serve to arrest the attention of chemists, and excite investigation, his object is attained.

The flattering reception of his two first Essays, encourages him to hope for the same indulgence, in the farther prosecution of the work. Though the novelty of the discussion can be no recommendation, it gives him some claim to this indulgence. In a path yet untrodden before, errors may be overlooked. They are at least more excusable, than such as are committed, in the beaten track which many tread.

SECTION I.

What is requisite to the formation of Moss.

In order that moss may be renovated when dug, it is requisite, that the pits be left full of water; that

they be not too large, nor deep; and that the water in them be stagnant. It appears that similar requisites are necessary to the original formation of that substance, either from ligneous or aquatic plants.

I. *Moisture seems to be absolutely requisite.*—Without it no moss is formed of these materials. Let a congeries of ligneous or aquatic plants be formed, however great that may be, if *left dry*, or not immersed in water, it never will be converted into peat. Such a mass indeed will, even in this case, undergo certain chemical changes, and form new combinations; but the result will be different from that substance. When exposed to the influences of the atmosphere, it will undergo the putrid fermentation, and be reduced to vegetable mould. In this form it will be destitute of the distinguishing qualities of moss, inflammability, tenacity, and others.

This is a point of considerable importance. Lest any doubt should remain on the subject, the following general remarks are subjoined.

1. It is known that all the deep mosses in Europe lie on level plains, where water must have stagnated. The very word, Mos, in the original Celtic language, implies this.

2. The subsoil of most mosses is impervious to water. It generally consists of a stiff tenacious clay. Sometimes sand may be discovered under that substance. But though it forms the immediate subsoil, below it an impervious bottom will be found, sufficient to prevent the water from sinking.

3. When moss is drained of superfluous moisture it ceases to grow. The aquatic plants which furnished the materials for its original formation and subsequent increase, no longer flourish. Of course no addition to the moss is made.

4. Mr Cordiner, in his account of Mar Forest, mentions a fact, which shews that, without moisture, no moss can be formed. "The greatest part of the "perishing leaves and branches, when left *dry*, were "converted into one general mass of vegetable earth. "In places where water had been allowed to stag-"nate, there, and *there only*, these materials were "converted into moss."

The same seems to be the case in the wood of Drumlanrig. The following facts have been politely communicated to me by his Grace the Duke of Queensberry's man of business: "Some part "of the forest fell across a small rivulet that run "through the marshy ground. At this place, there "is some mossy substance, which may have accu-"mulated from the damming of the water, and depo-"sition of its sediment. Yet it cannot be ascer-"tained, whether moss did not exist at this place, "previous to the fall of the timber.

"It is however, certain, that by far the greatest "part fell on *dry ground*, and that *here* there is "not the smallest appearance of mossy production, "though all the trees are quite decayed and gone. "There is only a rough foggy substance where they "had lain, where the grass is coarse. This last

" observation seems to shew, that the distinction you " point out in your letter, that water is requisite to " the formation of moss, is of importance."

If this be the case, and if moisture be absolutely requisite to the formation of moss, it is obvious that, where extensive forests abound, those regions must be more favourable for this purpose, than such as are destitute of wood. The climate in the former is always more damp than in the latter. The trees of the forest attract dew, prevent in a great measure evaporation from the soil, and occasion the waters to stagnate. By all these means the growth of aquatic plants must be promoted. Few of the musci are to be seen in the sunny side of a hedge. In the shade of the same hedge they flourish. The case is similar in a woody region. When the forests are thick set, every part of them becomes a shade, peculiarly favourable for the growth of such plants.

Besides this, when forests abound, springs, and of course rills and rivulets, are more frequent. Hence, Abbe Rozier observes, " That many regions, which " were formerly covered with wood, by being strip- " ped of it, are now become much less abundant in " springs. In vain (says he,) has Choiseuil searched " for the Sçamander of Troy. The forests of Mount " Ida have for ages been in ruins. And the sources " of the Scamander, have thereby been dried up." To the same purpose, he adds, " The plain of Mont- " morency has been celebrated for its fertility by " the pen of Rousseau. Now the forest of Mont-

"morency, is partly in ruins. The fountains, which "abounded in it, are of course dried up. The lake "is diminishing in size; and, when the whole forest "is gone, neither fountain, rivulet, nor lake will "appear."

If a woody region is always more abundant in springs, rivers, and lakes, than one destitute of wood, and if moisture be requisite to the formation of moss, it is reasonable to conclude, that this process must have been more rapid over the north of Europe 2000 years ago, than it is now. For, at that period, forests were certainly more abundant and extensive than they have been for centuries past.

II. *Moisture alone is not sufficient for the formation of Moss.* It is requisite for this purpose, that the water be stagnant. In the second essay, it has been shewn that, where a rill is permitted to run through a moss pit, there is no renovation of that substance. A current of water is equally unfavourable for its original formation or subsequent increase. To be convinced of this, it is only necessary to attend to the following facts.

1. Wherever a rivulet is allowed to overrun the surface of moss, aquatics cease to grow, and that surface is speedily covered with succulent herbs. This herbage being more delicate and tender, is speedily converted into vegetable earth. The moss disappears, and a fertile soil occupies its place, though the subsoil remains in its original state. This fact may be

established by examining all the mosses of Europe. The banks of all rills and rivulets, that run through moss, are covered with sweet herbage, as far as they are overflown; though the subsoil be still moss, and the whole surface adjacent, which is not exposed to the current, consist entirely of that substance.

The inhabitants of Duvels moor, are fully aware of this. M. De Luc observes, that "they form ditches "in this moor, that they may flood it at pleasure. "Sluices are placed in them, so that they can lay it "dry, when they please. And, wherever any part "of the moor is thus flooded, the moss ceases to "grow, and the surface becomes a rich meadow."

2. Having corresponded with this gentleman often, he mentions another fact in one of his letters, which claims attention. His words are: "In some "of the countries which I have surveyed with care, "there are exceptions to the *peatification*, of de-"cayed plants, which ought to be examined by "natural philosophers on the spot. One of these "exceptions, and the greatest, is the following. "There are dales, which externally exhibit the "same appearance, as others, in the country, "where moss is found. Through these *a river* "*runs*. Yet the horizontal plain, along the *banks* "of the river, contains no moss. It consists of "alluvial soil. What is the cause of such a decided "difference?"

May not the cause be this, that the water is not allowed to stagnate, on the banks? or, that these

plains are frequently overflowed by the current of the rivers? If no moss can be formed where a considerable current exists; and if the surface of Duvels moor be converted into sweet herbage, or rich meadow, by being overflowed by the art of the inhabitants, may not nature have performed the task in this case *?

Mr De Luc accordingly observes farther: "That "the decay of the plants that grow on the banks of "these rivers, and the adjacent plains, which are "thus overflowed, is followed by the putrid fermen-"tation. The water too, becomes putrid, and "emits those miasmata, which occasion fevers. "These lands of course become very fertile, more "so than peat-ground. But in the last, there are "no miasmata, and no putrid exhalations. The "air, on the contrary, is salubrious."

3. In the same letter, he mentions another fact equally interesting: "I have seen certain parts of the "circumference of some lakes (everywhere else bor-"dered with the advancing peat,) in which there "was no appearance of moss. These places were "shallow, and received the rivulets that run through

* Mr De Luc in his letters mentions a fact which tallies with this. "In Ostfrise, the country is low and nearly level. Of course, it is in "a great measure overflowed in winter. The *lowest parts*, which re-"main always flooded, are formed into mosses. Those which are only "occasionally overflown, and laid dry in spring, are converted into "meadows." Here nature operates without the feeble aid of art.

" the level. But in them, no reeds nor aquatics were " seen, and nothing led me to any conjecture as to " the cause of this. I have indicated these excep- " tions, because they certainly claim attention."

In consequence of a number of queries sent to him on the subject, he very politely furnished me with the following additional information on this subject: " In reply to your queries with regard to " the exceptions, I mentioned in my last, I had an " eye to a lake near Strelitz in Mecklenburg. A " small river runs out of the lake, fed by a number " of rivulets. Peat-moss surrounds the whole of " that lake, excepting at two points. The one is " where these *rivulets enter*, the other is on the op- " posite side, where *the river runs out*. There is " no peat in the course of the river, nor in that " part of the lake through which it runs. It is " shallow, on a pure sand, and there are no reeds in " its course. Yet both the rivulets which enter, " and the river that runs out of the lake, flow " through dales filled with moss. Such is the " fact. The question is, why is there no moss in " the track of the river?"

May not the current of the rivulets be the cause of all these phenomena?

May it not be the cause, why no moss exists in the tract of the river? Supposing that a mass of vegetable matter were deposited in such a current, it is not reasonable to expect, that it should be converted into moss. By being macerated in water, it

must give out the soluble particles it contains. The gallic acid, the tannin, the astringent juices, being all soluble, even in the recent state of the vegetable, must be washed away. And the longer this matter is macerated, more of it must become soluble. In the course of ages, the whole may be thus carried off by the current. That it is the soluble part of vegetables that contributes to the formation of moss, appears probable. For if this vegetable extract be evaporated, or if any chemical agent be applied to occasion a precipitation of it, when thus precipitated, the deposition it leaves possesses very nearly the qualities of moss. But where there is a current, no such deposition can take place. This vegetable solution must be carried off. The astringent juices of the recent vegetable, and the gums and resins, by becoming soluble, at a more remote period, may thus be removed. The vegetable matter that is left, must, in this case, be more liable to the putrid fermentation. On this account it may form fertile mould in place of sterile moss. At all events, the surface of moss in general is so level, that it seems never to have been exposed to such currents. The stagnation of the water, and the deposition of matter of course, seems to be requisite to the formation of that substance.

Though moss were formed in such a situation, it could not continue in that state, where a current of water was permitted to pass over it. This appears from the fact mentioned with regard to Duvels

moor. The soluble particles of the moss itself, must be carried off by the current. And when this is done, it ceases to possess the distinguishing qualities of that substance. M. De Luc accordingly observes, in the same letter, " that the dales filled " with moss are seldom if ever overflown, whereas " those which are covered with marshy soil are " very frequently." It becomes a loose, friable, fertile mass, scarcely inflammable at all. This may be proved by the following simple experiment. Take a quantity of newly dug wet moss, and let a current of water filter through it, even for a few weeks, its acidity will be removed, its tenacity destroyed, and it will cease to be so inflammable as it was in its original state. It will even become a fertile soil. May not the same process, on an extended scale, go on wherever a current of water is allowed to run over any moss? Probably this is one cause why none is found in the course of the rivers which M. De Luc describes.

It may be the cause, too, why no reeds nor aquatic plants are found in the course of the river. The seeds of these plants cannot strike root, where there is a considerable current. Some of these seeds are of the form of shells, or small canoes. On this account, they swim on the surface, and are carried along with the stream. They cannot take root, therefore, till the water stagnates. Others are furnished with fibres, which serve the purpose of masts and sails. By this means, they are impelled along

the surface of the water by the winds, even where there is no current. Of course, they cannot take root till they reach some sheltered corner. May not this be the reason why no reeds nor aquatic plants are found in the course of rivers such as M. De Luc describes? May it not be the reason, too, why moss is not renovated in pools where there is a current of water, or an extended surface, exposed to the agitation of the winds? Perhaps it may be the reason why extensive lakes, which contain a vast congeries of ligneous plants, and moss in their bottom, and whose waters, of course, are impregnated with vegetable extract, are not overgrown with aquatics, and converted entirely into moss. Loch Neagh, and Loch Sneagh are of this description. The waters of them, possess all the qualities of moss-water. But their surface is so extensive, and exposed so much to the agitation of the winds, that aquatic plants, requisite to convert them into morasses, cannot strike root.

There is still another consideration to be taken into the account. Wherever there is a current of water allowed to pass over the surface of moss, it must deposit a considerable sediment. That sediment must consist of all the varieties of earth, which existed in the soils over which it runs. Of course, it must form one of the richest composts over the whole surface. The whole must be covered with alluvial soil, consisting of sand, clay, calcareous earth; and many of the most valuable soluble salts.

No wonder, then, that such soils are so rich as M. De Luc describes. The current, and overflowings of the river, have been the cause of this. And nine out of ten of the richest meadows, and level grounds of Europe, have been formed in this manner, over the surface of mosses. Hence, the subsoil is almost uniformly of that substance, however rich the soil may be. Hence, a tuft of moss, in its original state, may be still seen, starting up in the centre of such rich level plains, as a monument of the state in which they once existed. These tufts are uniformly higher than the adjacent plains. The reason of this is obvious. They are the spots, from which the copious springs issued. Being heaved up by the water, and always higher than the rest of the moss, they have escaped the currents, and floods, to which the lower parts of the moss were exposed. Therefore they remain in their original state. And by the rapid growth of aquatic plants, they rise higher and higher annually. Layer after layer of vegetable matter, fit for the formation of moss, is deposited every year. But if such spots were reduced to the level of the adjacent lands, and like them overflowed; like them also they would, in the course of ages, be converted into fertile plains, and covered with rich alluvial soil.

The sand deposited in the course of the river which M. De Luc describes, must be owing to a similar cause. While the lighter particles, are carried along by the current, and deposited in level plains,

those which are specifically heavier, such as sand, must sink; even where the current is considerable. On this account, the course of the river, must be covered with successive strata of sand; and become shallow *.

So that it appears, that, in order to the formation of peat, the water must be stagnant.

* There are two obvious objections to this view of the subject. The first is, that moss is found on declivities, where water cannot be supposed to have stagnated. The second is, that it exists in low levels, occasionally overflown. To this it may be replied, that, in the first of these situations, the mosses that are found are shallow. They seldom exceed two feet in depth. They are, besides, less tenacious, and less inflammable, than low level mosses. A considerable proportion of their soluble ingredients are washed away by the rains. And they are generally covered with coarse herbage. Any *deep* mosses I have seen on *declivities*, seem to have been formed on higher levels adjacent, and been moved from their original situation. The ingenious Dr Graham of Aberfoyle, corroborates this observation, in a letter to me.

" I, every year, dig my peats in the top of a hill, at some distance from " me; about 500 feet above the level of the sea. This moss has a *de-* " *clivity* towards the north, and is ten feet deep in some places. I have " no difficulty in accounting for its formation. It appears to be a *dilu-* " *vian* moss. A vast quantity of vegetable matter has been swept " along, from the south west, which has been laid bare, and arrested " and *deposited* on this slope to the north-east. It has been prevented " from *sliding* farther down, by a rock which intercepts it at the extre- " mity."

Such as are occasionally overflown, in low level plains, are also different in their appearance, and chemical qualities, from real peat. They contain less hydrogen. Of course, they are less inflammable. They are always less tenacious; and generally so friable, that they cannot be formed into peat. They are called of course, rotten mosses. And, for the most part, they are covered over with grasses and succulent herbs. In short, they are already partly converted into vegetable mould.

III. *The water must also be possessed of certain chemical qualities, differing from rain or river water, in order to the formation of Moss.* Professor Robison expresses himself to this effect: "It "is by no means enough to the formation of peat, "that the place be a wet marsh, abounding with ve-"getable matter. In immense districts of Europe "and America, such situations are common; we "have impassable swamps of vast extent, which are "not filled with peat. I am inclined to think, that "a certain *juice* is necessary to the formation of "bogs into moss."

M. Findorf is decidedly of the same opinion. He observes, "that rain water, though it be allowed to "stagnate in vallies, or marshes, is always muddy. "That the aquatic plants, when overflown by it, are "not converted into moss, but vegetable mould. "Moss water, on the contrary, is not turbid or mud-"dy, though of a coffee colour. It seems to be of "an *embalming* quality. The sediment it leaves, "is also different from rain or river water. That "of the latter is of a greyish or ash-colour, and "not inflammable. That of the former, is of a dark "brown, approaching to black, and possessed of in-"flammability, like the moss from which it origi-"nates." M. De Luc makes a similar remark. "The very same plants which form moss, when im-"mersed in the latter, are converted into vegetable "mould in the former." This he ascribes to the antiseptic quality of the moss water. His words, in

his letter to me, are, " We agree in this, that the " antiseptic quality of the water is the cause why " vegetables are converted into peat. But the cause " of this quality is as yet unknown."

Some have maintained that moss-water differs nothing from rain or river water. Dr Anderson says, " that it is well known, that it possesses none " of the qualities ascribed to it. Nor does it seem " to possess any chemical quality, not common to " stagnant rain water, excepting, perhaps, a slight " tinge of a brownish colour, which may be ascribed " to the mechanical diffusion of minute particles of " moss."

A few facts may be mentioned, to shew that there is a difference, and to point out, wherein that difference consists.

1. Most of the plants which contribute to the formation of moss, are possessed of astringent antiseptic juices, soluble in water. When such plants are therefore immersed in that liquid in a stagnant state, these juices must be diffused through it. Of course, it must be changed in quality, and differ from that of rain or river water. When a quantity of oak leaves, or bark, or wood, or even aquatic plants, drop into a pool of stagnant water, a change of colour ensues, and it acquires a bitter astringent taste, and antiseptic quality. Aquatic plants, such as abound in moss, may flourish, even in such a liquid, though no succulent herb will. By this means, a mass of vegetable matter may be accumulated. And, in the

course of ages, that matter may be converted into moss. Still, the water may be expected to possess the same astringent antiseptic quality.

2. Accordingly, it is a well known fact, that, in this respect, moss water differs from rain or river water. The latter, when it is allowed to stagnate, especially in warm weather, becomes putrid; the former does not. M. De Luc has observed this difference. He says, "That the water in the Dutch "canals, is apt to become putrid in the heat of sum-"mer. By this means, they become a nuisance to "the inhabitants." Mr Dentan makes a similar remark. He adds, "That an elastic and inflam-"mable gas rises from the bottom of the water "in the canals, when it is stirred with a staff. He "collected this gas, in an inverted cylinder of glass. "When a lighted candle was applied to it, it took "fire." Brissons calls this the gas of the marshes. Moss water, in the same latitude and climate with these canals, is not liable to such a change, and yields no such gas. M. De Luc takes particular notice of this fact. He says, "that the moss waters, over all "Holland and Hanover, and the continent of Europe, "are not liable to the putrid fermentation." Mr Macard says the same. He ascribes this *distinguishing quality*, (as he calls it) to the bitumen they contain. Dr Rutty, in his Essay on Mineral Waters, observed the same *peculiarity*, and ascribed it to the same cause. In this respect, therefore, it differs from rain and river water,

3. Moss water is possessed of an antiseptic and embalming quality. It not only remains pure and free from putrescency, but it retards the putrid fermentation both of vegetable and animal matter immersed in it. That the ligneous and aquatic plants lodged in it are found in a state of unusual preservation is doubted by none; and that all the parts of animals have been preserved for ages in it cannot be denied.

The oak stakes, taken out from the banks of the Thames, are a sufficient proof of the former. These are known to have been placed there by Julius Cæsar, nearly 2000 years ago. Yet they are solid and compact, and seemingly bituminated*.

* Dr Anderson thinks that these oak stakes have been preserved by the water of the Thames. It is certain, however, that it is the moss on its banks that has been the mean of their preservation. From the account that Cæsar himself gives of the extended level around London in his days, it appears to have been all covered with impenetrable woods and impassable morasses. Though now converted into extensive meadows and arable lands, and partly covered by the buildings of the city, the *subsoil* is *still moss*. And immense trees have been dug out of it; the relics and indications of its former state. In the year 1708, (Phil. Trans. No. 335.) it is said that there was an inundation of the river. A large channel was thereby cut through the adjacent level. This channel was upwards of 100 feet wide and 20 deep. A great number of trees were thereby laid open. These all lay in a *mossy marsh*. The fibres of them were as tough as wire. Many thousand acres along the banks of the river are of this description. And the same appearances have been discovered at Rainham, Wenningham and West Thanock. The soil of all that district is a black oozy earth, full of roots and reeds. Seven feet, and in some places twelve, of alluvial earth is to be found on the surface. But the *subsoil* is uniformly the same, and *trees* are found buried in it.

The innumerable animal bodies, that have been discovered in a complete state of preservation, are sufficient proofs of the former.

4. Moss waters seem to contain tannin. For the skins of all animals found buried in them, have undergone an operation similar to tanning. They are always harder, thicker, and tougher, than those of

When the wet-dock at Deptford was built, 100 years ago, hazle and oak trees were dug out of the foundation. At a later period, a similar stratum was laid open at Blackwall, in digging the wet-docks on the opposite side of the river. In this, similar trees were discovered, and peats were dug out of it. When the docks were built in the Isle of Dogs, the subsoil was found to be *moss*, yielding peat. And Captain Berry, in his account of the stopping of Daggenham Breach, says, that all along the banks of the river, peat moss is found, from 6 to 9 feet deep.

Dugdale, in his history of draining, mentions, that a great part of Southwark is built on a mossy foundation. The houses are built on piles. Diverse Roman coins have been dug out of it. He says, that he saw, in the year 1658, in Southwark Park (behind Winchester house) a Roman pavement dug up 2 feet below the surface. It was made of bricks. Adjoining to it, he saw a more curious piece of workmanship of the same materials; it was of various colours, like Mosaick work. The whole of Moorfields, was a fen, extending over Bishopsgate, Cripplegate, Finsbury, Holywell, in the reign of Edward II. It was such a waste that it was let for 4 merks a-year. Even in the year 1415, it was all overgrown with flags, reeds, and rushes. Fleet-Street stands on a similar foundation. In the year 1595, in digging four feet deep under the pavement in Chancery Lane, up towards St Dunstan's church, another pavement of stone was found. Under this pavement piles of wood were discovered, driven close together. This wood was as black as coal.

If Julius Cæsar drove his piles into the banks of the Thames, they must have entered into this mossy subsoil, which extends, in all directions, around the spot from whence they were taken. If so, they must have been preserved in the same manner, and by the same means, as the other piles and pieces of wood mentioned above, *i. e.* by the moss.

living animals of the same species. In this respect also they differ from rain and river water.

5. Moss water converts all the vegetable matter immersed in it into moss. This is not the case with rain or river water. A few facts may be stated to shew this difference. M. De Luc mentions one; he says, "that in the plains of Twickle, there is a "water which oozes through the sand to the sur-"face. It originates from a stratum of moss below "it, and is impregnated with a black substance. "This communicates to the water the colour of "coffee. When this water descends into the adja-"cent plain, and becomes stagnant, it leaves a sedi-"ment, which, of itself, makes very good moss, of "which the inhabitants make peat." He adds,

"In some places, where the operations of nature "are unmolested, the lakes formed by this water, are "filled with aquatic plants. These do not undergo "the putrid fermentation. They are not completely "disorganized. On the contrary, they are convert-"ed into moss highly inflammable. It is akin to "the mosses of Bremen, but more compact."

It is well known, that the rain water which falls on heath, when allowed to stagnate, acquires a similar tinge and leaves a similar sediment. M. De Luc also takes notice of this. A simple experiment will establish the fact. The Earl of Cromarty of course concludes, that a similar water is the parent of peat. His words are, "I never observed any deep mosses "which did not lie on plains, albeit heath and turf

"overspread the face and declivities of the mountains, and many of their tops. Yet deep mosses are only to be found in plains. And the water that descends from these higher grounds, I take to be the parent of peat."

It is superfluous to add, that all moss water leaves a sediment similar to what is mentioned above. It is likewise uniformly of the same colour. The quantity washed down perpetually from the higher grounds must be immense. And the sediment it leaves in the plains, where it stagnates, must be great. Some considerable rivers are so tinged with it, at all times, that we may trace their origin to moss, through all their course, however long it may be. And every rivulet that runs over the surface of mosses, when swelled by floods, is tinged of the same colour. Yet these rivers have continued to run, and continued to deposit this sediment, ever since moss began to be formed on the higher grounds over which they flow. The quantity, therefore, deposited in low levels where these rivers stagnate, must be great indeed. And, while moss exists on such declivities, and rivers continue to run, there must be a perpetual accession of this sediment, wherever they are allowed to stagnate.

Besides, if water, impregnated with such a sediment, possesses the power of converting vegetable matter into moss, like that which M. De Luc describes, we are at no loss to account for the formation of the deepest mosses that have hitherto been discovered. In the two former essays, it has been shewn, that a

sufficient quantity of vegetable matter may be accumulated for the purpose, by a simple and certain process in nature, which is perpetually going on. And if stagnant water, possessed of the above qualities, be sufficient to accomplish the change, and convert the whole into moss, it is easy to account how that substance has been formed, even of the depth of ten, twenty, or forty feet.

From all these facts, we may conclude, that moss water must be possessed of certain chemical qualities, distinct from rain and river-water, in order to convert vegetable matter into moss. It is vain to assert, that the peculiar colour of it is owing to the mechanical diffusion of the particles of moss floating in it. Whatever matter be the cause of that colour, it is clear, that it is held in it, by chemical solution. For however dark that colour sometimes is, moss water is never turbid. No particles of moss, or any other matter, can be observed floating in it, even by the aid of the finest microscope. When any chemical test, is applied, then it becomes turbid. When calcareous matter, or carbonic acid, or gelatine, or muriate of tin, is poured into it, then it assumes a turbid appearance, and yields a copious precipitate. All this shews that the colouring matter is not only mechanically diffused, but held in chemical combination, in the water.

IV. *Besides all the above requisites, a low temperature, seems to be necessary to the formation of*

moss. It is superfluous to offer any proof of this. One fact is sufficient to establish it. That no moss exists in warm climates. It has seldom, if ever, been discovered between the tropics. Even in the South of France and Spain, it is seldom found in the vallies. On the summits of lofty mountains, even in a more southern latitude, it may be found. But there, a low and almost equable temperature reigns, all the year round.

While no moss exists in warm climates, it abounds more and more, in proportion as we advance farther from the equator. It is much more frequent, and more inflammable, in the north, than in the south, of France. The same is the case in Britain, and all Europe.

It is not said that none has been discovered, in the southern hemisphere. The probability is, that it abounds in many regions of it. In South America, and especially on the Peruvian mountains, it has certainly been discovered.

This, however, does not invalidate the assertion, that a low temperature is requisite to the formation of moss. On the contrary, all these facts seem to corroborate it.

Whether the temperature of Britain, and the north of Europe be lower, or the climate colder now, than in the age of Julius Cæsar, it is not said. This is indeed a popular, and prevailing opinion. Many circumstances have been alleged, in proof of it. Most

of these proofs seem to be more plausible than satisfactory*.

The only decisive evidence, that the north of Eu-

* 1. That the harvest, in the south of England, where Cæsar landed, was finished by the 26th of August; is no decisive proof of this position. Many harvests have been as early as that mentioned by the Roman emperor.

2. That he represented Britain, to his soldiers, as a milder climate than Gaul, is still more questionable. His object in making this representation might be, to encourage his legions to land, and subdue the island.

3. That the natives of Britain wore no clothes, at that period; is a proof that they were in a savage state; but it by no means amounts to a presumption, that the climate was milder. There are savages still, who roam through the most dreary regions, and inhabit some of the coldest climates of the earth, without any covert. This surely can never be adduced as an evidence, that their climate is milder than that which their more civilized fellow-creatures inhabit, who are clothed in purple and fine linen.

4. That immense trees, such as do not now exist on the surface, have been dug out of our mosses; is no direct or decisive proof of the mildness of the climate, at that early period. In all woody and uncultivated regions, such as America and Russia, even where the climate is much colder than Britain, such immense trees are still to be found

5. That fewer cattle are now reared on the same spot than formerly, is a very equivocal proof of the point at issue. At that period, the cattle, like the rein-deer of the mountain, were suffered to range at large, as over a vast common. Unmolested by man, they must have multiplied more. Besides, ten of these wild cattle might subsist, where two of our domesticated stock would starve.

The immense forests, too, furnished extensive pasturage in summer, and a considerable quantity of winter fodder. From the different chartularies quoted by Mr Chalmers, in his Caledonia, it appears that horses and cattle, and swine, were permitted to roam at large, through these forests. And the quantity of hay, which they furnished, was so considerable, that it was subject to tithe. The forests of Blair and Forfarshire, furnished one-tenth of the hay to the monks; whereas these forests,

rope and Asia, is colder than it has been *at some very early period*, is, that trees are dug out from under the perpetual snows of Lapland, and Iceland, and

now in ruins, or converted into moss, can neither furnish pasture nor fodder. Not one particle of hay, is produced on them. And 500 acres of some mosses, would scarcely feed one cow, where a hundred might formerly have abundance, of summer, and winter food.

6. That masts of ships were commissioned from Britain to Italy, as the latter could not furnish them, is, by no means, a satisfactory evidence, that our climate was milder then, than it is now. As large trees, and as fine timber for masts, are brought still from Sweden and Norway as any which Britain ever afforded. Yet it is well known, that the climate of these countries is colder than ours. It is a proof, indeed, that Britain is now, what Ptolemy represents Italy to have been, in that early age; stripped of its forests, and obliged to have recourse to these colder regions, as Italy was to Britain, for their masts.

7. That wheat was reared, some centuries ago, where none is now cultivated, is no positive proof that the climate is colder now, than at that period.

At that early age, the farmer enjoyed many advantages. The vast woodlands which skirted every where the arable lands, gave shelter to the crops, promoted their growth, and augmented their produce. These woods, were of still greater advantage. In place of being, what they now are, bare, bleak, and barren mosses; they afforded much pasturage for the numerous herds and flocks that were reared. Thus the husbandman was enabled to raise more grain, and rear more cattle, than modern prejudice will readily believe.

Mr Chalmers, in his Caledonia, shews, that forest-mares for breeding, were so numerous in the 13th century, that they were tithed. By his indefatigable labours, too, he has shewn, from his research into chartularies, and ancient records, that the operations of agriculture were countenanced, and carried on with much more spirit than is generally supposed. The highest orders of society, embarked in this most honourable and useful profession. The sovereign himself set the example. The great barons followed it. The bishops and monks, with all their skill and assiduity, followed in their train. They had most knowledge, from what they had seen in other countries. They had most capital, and the com-

even on the summit of the Alps, and Pyrenees. That these trees grew on the spot where they now lie, cannot be doubted. And that no tree, nor vestige of vegetation, can now be traced in these regions, is equally certain. At the period therefore, in which these trees sprung up and flourished, the temperature of these northern regions, and lofty mountains, must have been much milder than now. But that period seems to have been far more remote, than the Saxon, or even the Roman age.

At these ages, the climate of the north of Europe,

mand of many hands. They enjoyed too, more quiet, and security, and freedom from taxation, and public service. They subdued the woodlands, cultivated the wastes, inclosed the arable lands with fences, formed roads and bridges, and, by all these means, rendered the whole more productive.

At that period, too, he shews, that oats and wheat were chiefly raised. Little barley, and almost no green crops, were cultivated. Of course, the whole dung and manure, was applied to wheat land. On all these accounts, the culture of that valuable crop, was raised to a high pitch of perfection. Insomuch, that though the higher orders of society, used only wheat bread, yet, during the Scoto-Saxon period, enough was raised for home consumption, and some was exported from Berwick and Leith. The proportion of wheat thus raised, was, on these accounts, far greater than has been generally supposed. Hence, in the chartularies, there is often an equal quantity of that grain, and oats, granted to the church. William the Lion gave, to the bishops of Rochester and Salisbury, when they retired to Scotland, 1280 b. wheat, 1280 of oats, and 1056 malt.

It is to these causes, and these great exertions of skill, and expenditure of capital, that we must ascribe the vast proportion of wheat and other grains, raised at these periods; more than to the effect of climate. That less grain is now cultivated, is no certain proof of the deterioration of that climate.

seems to have been equally cold, as it is now. Both Diodorus Siculus and Julius Cæsar declare, that the rivers of Gaul, were frozen over *every winter*. That horses and chariots, and whole armies with their baggage, passed over them with safety.

That the immense forests afforded extensive shelter at that period, cannot be doubted. But that they occasioned also a degree of *dampness* in the air, is equally certain. And that the greater degree of evaporation of that dampness, must have generated cold, seems equally clear. There appears, therefore, little cause to join the general cry, that our climate is so much worse than it was in the days of our fathers, ten or twenty centuries ago. And there seems to be as little reason to conclude, that the mosses of Europe have caused such deterioration of climate, as has been supposed. That they afford less shelter than the lofty forests that adorned the spots that they now occupy, cannot be doubted for one moment. But that they occasion more dampness, and a greater degree of cold, seems to be questionable.

If, however, a more cold climate be favourable to the formation of moss, than one that is warm; and if the climate of the north of Europe, be indeed so *much colder, and more damp than it was some centuries ago*; *we may safely draw the following conclusion; that this substance must be formed with more rapidity, and to a greater extent than formerly.* And if this change of climate be indeed progressive, and

the degree of cold becoming greater from age to age, the formation of moss must not only go on, with proportioned rapidity, but it must advance farther and farther south, till at last it may exist under the equator itself.

Nothing can tend more to elucidate the natural history and origin of moss, than to ascertain, with precision, what is requisite for the formation of that substance. If once ascertained, this may furnish a key to unlock the whole mystery. For if moss is never formed where there is not much moisture; and if the water, which seems to be a necessary agent, must be stagnant; and possessed of the *chemical qualities* specified above; and if a *low temperature* be equally necessary to carry on, and complete this process; it will then be more easy to ascertain the means by which it is accomplished. All that is necessary for this purpose is, to point out the changes which vegetable matter undergoes, when placed in such a medium, and such circumstances; and the consequent combinations, which that matter must form. This shall be the subject of the following section.

SECTION II.

The changes which animal matter, undergoes, in different mediums, are very different. Exposed to the influences of the atmosphere, it is decomposed in

one way. Buried in the earth, or immersed in water, especially if that water be possessed of the qualities abovementioned, and kept in a low temperature, the decomposition of it is either retarded, or when accomplished, it is by a different chemical process. The residuum in the one case, is therefore different in its chemical qualities from that of the other. Different combinations are formed in these different mediums.

A similar difference exists in the residuum of vegetable matter, when decomposed in these different mediums. And the combinations it forms, are equally different. This distinction, seems to have been overlooked. On this account, many have formed erroneous opinions, as to the origin and qualities of peat moss.

In the subsequent part of these Essays, this distinction shall be constantly kept in view. It may probably furnish one datum, which may throw some light on this intricate branch of natural history.

As the changes which animal matter undergoes, in these different mediums, have been ascertained, and found to be very different; it may be proper to exhibit a short sketch of these in this section. By tracing the analogy between these changes, in animal, and vegetable matter, in these different mediums, a ray of light may perhaps be reflected on both.

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1. When exposed to the influences of the atmosphere, and the alternations of heat and cold mois-

ture and drought, all animal substances rapidly undergo the putrid fermentation. During that process,

In the *first* place, The carbonic acid is formed, then disengaged, in a gaseous form. This acid, seems to operate, as an antiseptic to that matter; while it continues in combination with it. For no dissolution takes place, and the putrid fermentation is never accomplished; till it be discharged. When the dissipation of this acid, is arrested; that process is at a stand. A variety of experiments have been made, to prove this. M'Bride and others, have, by this means, ascertained the fact. When morsels of flesh, which had already become partly putrid, were plunged into the carbonic acid; the putrid fermentation was arrested.

Secondly, After a large proportion of this acid is evolved, the hydrogen also escapes, in a gaseous form. These two gases are highly deleterious. No living creature can breathe, for any length of time, in such tainted air. A few inspirations of either, would suffocate any animal. Probably they are the chief causes, why burying-grounds, and those places where the putrid fermentation of animal substances takes place; in open air; are so dangerous to the health.

Thirdly, The azote, which abounds in such substances, is likewise evolved. Uniting with the hydrogen, in its nascent state, it forms ammonia, or volatile alkali. The consequence of this is, that the air acquires an acrid pungent smell.

Fourthly, During the last stages of this process, the oxygen of the external air, combines, with the azotic gas; and forms the nitrous acid.

Fifthly, Other changes and combinations are no doubt effected. Hydrogen, when disengaged, dissolves the sulphur, and phosphorus; and part of the carbon; contained in animal substances. Uniting with the first, it forms sulphurous hydrogen gas. This is also evolved; and communicates a fetid odour, to the air; similar to that of rotten eggs. Combining with the second, it forms phosphorated hydrogen gas. The odour of this is also fetid. But it is different, from the former. It resembles more, the smell of putrid fish. By uniting with the third, carbonated hydrogen gas, is formed. The odour of this is also strong, but distinct from the other two.

Lastly, After all the volatile particles, are thus discharged; nature has finished her task. There is a complete dissolution, of the animal frame. No trace of organization remains. The most delicate mechanism, and the most beautiful form, is totally destroyed. Or rather, it is reduced to its elementary principles. And each of these being set free, is prepared to form new combinations. All that remains, of what was once so lovely, delicate, and beautiful, in the animal frame, in an organized state; is an insipid blackish carbonaceous matter; not distinguishable from the clod of the valley.

II. The chemical agents, which cooperate, in producing these changes; have been, partly ascertained.

In the *first* place, the oxygen of the atmosphere, is the great, and primary cause. Accordingly, the purer the air is, or in other words, the more oxygen it contains; the more rapid are, these changes. Pure oxygen, is the most powerful, of all agents.

Secondly, A certain degree of moisture, seems also to be requisite, and cooperates in effecting these changes. If animal matter be kept perfectly dry, the putrid fermentation is greatly retarded; and few of the changes and combinations, now mentioned, can take place. Rozier observes, in proof of this, "that the misera-"able travellers, who perish in the parched sandy "deserts; are not liable to these changes. Their bodies are discovered, without any marks of disor-"ganization. Though parched and shrivelled, they "are preserved, from dissolution." While a total want of moisture retards, this process; too much, as I shall have occasion to shew, is equally unfavourable for that purpose.

Thirdly, A moderate degree of heat, as well as moisture, expedites the process. Indeed, caloric seems to be a necessary agent. It dilates the fluids; *and dissipates the volatile particles*; *in the form of gas*. If the temperature be low, that is, near to, or below the freezing-point, the process is arrested, or at least retarded. If very high, on the contrary; the volatile particles are rapidly dissipated. But, in this case, the disorganization is not completed. The

moisture, requisite for the purpose, being dissipated; and the body laid dry; by this high degree of caloric; becomes parched, and shrivelled. Therefore, only a *moderate degree* of heat, is requisite; for this purpose. A very high degree, arrests the process; or prevents its completion.

Fourthly, The alternation of temperature, or of heat and cold, especially if the transition be rapid and frequent, expedites, the process. Alternate moisture and drought, operates to the same effect. Whereas, an equable temperature, or continued moisture, or continued drought, arrest the putrid fermentation in a great measure. Experiments to prove this might have been stated.

Lastly, Access to the air, seems requisite for this purpose. Secluded from this, the process cannot advance. Animal matter *in vacuo*, does not undergo the putrid fermentation. It appears even, that stagnated air is more favourable for promoting this, than a current of it.

These are some of the most remarkable changes, which animal substances, undergo; in the above medium.

The changes and combinations, which the same matter, forms in the medium of water; are very different. And the residuum, is also possessed of very different qualities.

III. Immersed in water, it would appear, that animal matter, undergoes; the following changes.

In the *first* place, the soluble carbon, uniting with the oxygen of the water, may, even in this medium, form, carbonic acid. But in place of being evolved, altogether, in gas; it must combine partly, or be diffused through the water; to which it has a powerful affinity. This acid, being a powerful antiseptic, may contribute its part, to arrest the putrid fermentation.

Secondly, The azote, too may combine; in this medium, with hydrogen; and form ammonia. But, as this also, has a powerful affinity to water; it is not all *dissipated* in the form of gas.

Thirdly, After the azote is set free, from animal matter; the residuum that is left, chiefly consists, of carbon and hydrogen. These are the bases, or rather elementary principles, of all oils. Combining together, in this medium; they form a concrete oleaginous substance; like spermaceti. The oxygen of the water, or perhaps the various acids, diffused through it; may be the cause. why this matter assumes a concrete form; at least, when oxygen and the acids are expelled, from that matter by distillation; it resumes the liquid appearance of oil.

Lastly, The result of the whole is, that less hydrogen, and less carbon, is disengaged from animal matter, immersed in water; than from that which is exposed to the influences of the atmosphere. The residuum, in the former case, must contain more of the inflammables; than in the latter. This might be expected *a priori*. And the fact answers our expectation. While the residuum of animal substances

exposed to the air; is, as has been stated, a blackish carbonaceous matter, like mould; and almost destitute of inflammability; that of the same substances, in the medium of water; is an oleaginous concrete fatty matter; highly inflammable. The above statement may appear to some, totally foreign to the subject, under discussion. Especially, as it has all along been supposed, that moss is entirely composed of vegetable matter. To this it is replied, that the elementary principles of which vegetables, and animals, are composed; are mostly the same. The chief difference that exists, between them, is this; that only a *few* of the former contain azote: the latter always abound with it. In other respects, they yield almost the same simple elementary principles, by distillation; only in different proportions. After they have undergone the putrid fermentation, too, the *residuum* that is left is *nearly the same*. At least when that process is completed. And the intermediate changes, through which they pass, are similar. The agents, in both cases, are the same. The analogy between these, therefore, is obvious; and it may be useful; and tend to elucidate this subject.

More especially, as it is ascertained, that a similar difference, exists; between vegetable matter decomposed in different mediums; as in animal substances. And still more, when it can be proved, that the residuum is *equally different*; owing to the same causes. To state the changes and combinations which vegetables undergo; shall be the subject of the next section.

SECTION III.

THIS is the most important point in the discussion of the subject. If clearly illustrated, it would throw a ray of light, on the natural history of peat moss; and enable us to ascertain, the manner, and means, by which it is formed; and the precise state, in which it now exists. By this means, too, we may clearly ascertain, in what respects it differs; from the recent vegetables, of which it is composed. The task is difficult. With the utmost diffidence, do I now undertake it.

The changes, which moist vegetable matter, undergoes; in the medium of the atmosphere.

These are similar, to the putrid fermentation of animal matter; and effected, by similar agents. The process is however, slower, in vegetable; than in animal matter. In the first stages, of that process; there is little, or no dissipation of gas. Till the temperature of the mass, be raised, above the medium of the air, of a cold climate; no gaseous fluid is evolved. Before the putrid fermentation, commences; the temperature, uniformly rises; though, in warm climates, it goes on, though below that of the air. A variety of changes take place; new combinations, are then formed; and various gases are evolved.

In the *first* place, the oxygen of the air, combines with the soluble carbon, of the vegetable; to form carbonic acid. While that acid remains; no disor-

ganization, or at least, complete dissolution, takes place. Whereas, when it is dissipated; dissolution speedily ensues.

It seems, thus, to be the great antiseptic. As such, it operates, on all fermented liquors. By it, they are preserved, from becoming putrid. When it is expelled, they become flat, and insipid; and soon assume a putrescent appearance. Of this, any person can satisfy himself; by a simple experiment. Take a bottle of beer, or porter, and expose it, in an open vessel, to a slow fire; by this means, if the temperature be raised sufficiently, the carbonic acid will be nearly expelled. The liquor, will no longer partake, of its former pungent acid taste. It will become flat, and speedily acquire a putrid flavour. On the contrary, a bottle of these liquors, though flat, if placed in an open vessel, over a vat where fermentation is going on; or if by other means, it be impregnated again with carbonic acid; it will again become brisk, and pure.

The case is similar with vegetable matter. When the carbonic acid is expelled, it speedily becomes putrid. The process may be observed in fruit. When quite fresh, an apple is hard. By exposure to the air for some time, it becomes softer, and more spongy; till at last, it is reduced, to a pulp. In this state, its acid taste, is nearly gone.

Any mass of vegetables, exposed to the air; experiences similar changes. It attracts the oxygen, of the atmosphere; to which it is exposed. This com-

bines with the carbon, of the vegetable; as has been said, to form carbonic acid. But this combination, uniformly raises the temperature, of the mass. A certain degree of caloric, is generated; or thereby combined with it. That degree is generally from 60 to 80. In the former temperature, the process is slow; in the latter, it is rapid; and the carbonic acid, then assumes, a gaseous form, and flies off.

This evolution, is obvious, to the senses. It is visible to the naked eye, in the fermentation of grain; in a vat. Numerous globules of air, rise, to the surface. An intestine motion, is seen; and, when the process is rapid, the liquor is violently agitated. It bubbles, and boils, and foams. The carbonic acid, is evolved; being specifically heavier than the atmosphere, it hovers over the vat; and communicates a sharp acid-pungent odour all around it. The same odour may be detected; when a bottle of these fermented liquors, is exposed, to this high temperature. They emit no such acid fumes, while kept below it, say at the temperature of 40, because the carbonic acid, is not evolved, in a gaseous form.

Secondly, When the process is allowed to go on; and the fermentation advances towards the last stages; the hydrogen, contained in vegetable matter; is set free. Being specifically much lighter than the atmosphere; it assumes a gaseous form, whenever it is set at liberty, from its former combination. In the process of fermentation, this uniformly takes place. And when that process, is allowed to proceed, in open

air; it is almost entirely expelled, when the putrid fermentation is completed. The residuum, becomes therefore, nearly destitute of inflammability.

If the process, however, be arrested in its early stages, of the acetous fermentation; the residuum is different. Possessing still a great proportion of hydrogen; it is *more* inflammable.

Thirdly, Along with the carbonic acid, or rather as forming the basis of it, carbon is partly dissipated; during this process. That which is already in a state of solution; by combining with oxygen, to form the above acid; is expelled in the form of gas. When the hydrogen, too, is set free; it operates as a solvent of carbon. These combining together, form carbonated hydrogen. This also flies off in gas; and thus another portion of carbon is evolved. This uniformly takes place, during the putrid fermentation. When water is allowed to stagnate, in warm weather; this gas is formed, and rises spontaneously. Hence, Mr Volta discovered it in the pools of Italy; and Mr Dentan in the Dutch canals.

Fourthly, Part of the sulphur and phosphorus of vegetables, is dissipated, by a similar process, as from animal substances: that is, in the form of phosphorated, or sulphurated hydrogen gas. The former of these is so highly inflammable, that when it comes in contact with the air; and still more with oxygen; it spontaneously takes fire. Hence, in marshes, and low levels, where the putrid fermentation of vege-

tables is carried on; lambent fires, are often seen, in the night.

Finally, The putrid fermentation proceeds on the same principles as combustion; and produces similar effects. The only difference, that exists, between these two processes, is, in the degree of rapidity, with which they are carried on. The latter is always more rapid. Yet the rapidity of the former, in certain circumstances, is so great; that it cannot be distinguished from, or rather occasions, combustion. In hay-stacks, or heaps of grain, or dunghills, the fermentation is often so rapid, that they sometimes catch fire, and burn with impetuous fury.

If the above view of this subject be correct; if all vegetable matter in the medium of the air undergoes the putrid fermentation; if during that process, a great proportion of the carbonic acid, if a considerable part of the hydrogen, and some part even of the carbon it contains, be dissipated in gas; it is natural to expect, that, by being stripped of the first, they will become specifically lighter; deprived of the second, they will become less inflammable; and robbed of the third, the residuum will contain less carbon, than the original vegetable in a recent state. The case is precisely what might have been expected *a priori*. Oak, is one of the heaviest of woods. When exposed long, to the influences of the atmosphere; and thereby robbed in a great measure of the acid, it contained, it becomes much lighter than it was. Fir, or resinous wood, is one of the most inflammable, as it contains

the greatest proportion of hydrogen. When it is long exposed to the air, and robbed of this; it becomes much less inflammable. And both these species, as well as every other vegetable, leaves, in this case, a much smaller residuum of carbon, than it possessed in its recent state.

These are a few of the most remarkable changes which vegetables undergo in the medium of the air.

II. *The causes of these changes; and the agents that co-operate in effecting them; are the same, as in animal matter.*

In the *first* place, the oxygen of the atmosphere operates, in a similar manner, on the former; as on the latter. And it is as absolutely requisite, in the one case; as in the other. In vacuo, or without access to oxygen, no such changes ensue in vegetable, any more than in animal matter. This may be ascertained, by a simple experiment. Take a quantity of grapes, which are of all vegetables most liable to fermentation; let these even be pressed, in which case they are in a state of preparation, for that process; place them in this state in a vacuum, they may remain there for years, without undergoing such changes. On the contrary, let them be removed, and placed in the open air; they will speedily ferment; and that process, will advance with rapidity. Ripe cherries, have been preserved, for forty years, in a vessel well luted.

Thus, without access to oxygen, there is no dissolution, no change. It is the combination of this gas, either by the slower process of fermentation, or the more rapid of combustion, which dissolves the cohesion, and destroys the texture; of all vegetable, as well as animal matter.

Secondly, A degree of moisture is as requisite to that process, in the former; as in the latter. The manner, too, in which it operates, in the one case, is the same as in the other. The component parts of both, are held in chemical solution, in the water. And according to the laws of chemical affinity, there can be no combination, between the particles of matter; without chemical solution. It is not enough that these particles be pounded, mechanically, into an impalpable powder. The smallest particles, of the finest powder, formed by the art of man; are like mountains, when compared to those, formed, by the operations of nature; in chemical solutions. And without moisture, no such solutions can take place. Of course the changes and combinations, above-named, cannot be formed.

Hence, hay, straw, grain, or any vegetable perfectly dry, may be preserved for ages, in that state; without the smallest symptoms of fermentation. The wheat, discovered in the Roman forts; between the Forth and Clyde, was as free of fermentation, as when it was lodged there; though it must have lain nearly 2000 years. On the same principles, grain that is kiln dried, if kept from moisture, (as the Roman

wheat probably was) may be preserved, for any length of time.

Even the softer vegetables, such as grapes, apples, and pears, and those which contain most saccharine matter, and are thereby most liable to fermentation; may be preserved from undergoing that process; if kept free from moisture. Of course, when these are kept whole and unbroken; they are not so liable to that process, as when they are mashed and bruised. The reason of this is, that, in the latter case, they are more moist; in the former, there is not a sufficient degree of moisture.

Nay, a lump of sugar, while it is kept dry, will not ferment. But, if thrown into water, and thereby dissolved; that process will soon commence.

Thirdly, A certain degree of caloric, expedites this process, in vegetable; as well as animal matter. It also operates in a similar manner; on the former; as on the latter. It expands, and opens the pores, of vegetables. Their volume being thus enlarged; the oxygen of the air has freer access; of course, its operation is more powerful; and the fermentation it occasions, is more rapid. By that fermentation, too, a greater degree of caloric combines, till the temperature is raised to that pitch, in which the volatile particles of the vegetable, are almost entirely evolved in gas; in other words, till the putrid fermentation is complete.

But if vegetable matter, be kept continually, in a low temperature; no fermentation, no evolution of

gas, no putrescency can take place. Fourcroy observes, "that no fermentation of vegetables takes "place, if they are kept below the freezing point. ' That for the most part, it never commences till the "temperature be raised, above 50 degrees of Rheaumur. That, on this account, that process is entirely "at a stand, under the poles; and even in other regions of warmer climates, during the winter's cold. "Whereas, on the contrary, that process is carried "on, with all its rapidity and force; in regions of high "temperature."

It is on this account, that fruit of all kinds, even the softest and most pulpy, may be preserved in an ice-house. But whenever fermentation commences, heat is generated. The combination of the oxygen with the carbon, is the cause of this. And the more rapid this combination, the more caloric combines also with the mass.

A simple experiment, establishes this. Take a quantity of spirit of wine, and as much water, and place these liquids in different vessels; in the same place; no change will take place in either, of course, no change of temperature. Fill, however, a third vessel, partly with the one, and partly with the other of these liquids; this mixture will speedily undergo a change. The temperature on this account, will rise in it; while that of the other two, though placed in the same situation, and circumstances; will remain unchanged.

The cause why a mass of vegetable matter, during fermentation, rises in its temperature, is precisel the same. And in proportion as the fermentation advances; that is, in proportion as the union of oxygen and carbon is formed; the heat is increased. When the carbonic acid, which is the consequence of this union, is disengaged; the fermentative process is accomplished; and the whole mass gradually cools.

Fourthly, The alternation of heat and cold, moisture and drought, is equally favourable to the putrid fermentation, of vegetable; and animal matter. And the more rapid and frequent this alternation; the more rapid also, is the fermentative process. An equable temperature, whether high or low, and continued moisture or drought, arrests that process; or at least greatly retards it. Whereas, sudden transitions, from the one of these to the other, tend to destroy the texture of vegetables, by the rapidity of fermentation.

These two positions are important, and deserve attention. The former will likely be readily admitted, that an equable temperature is unfavourable to the putrid fermentation. The fact is ascertained, that the tenderest vegetables may be preserved in a temperature that is *uniformly* low. It is certain also, that even at a high temperature, if kept uniformly in that degree, without alternation or change, no fermentation of vegetable matter takes place.

If this be the case, the other position must be allowed to be well-founded, that it is the alternation of temperature, and the transition from moisture to

drought, that promotes this process, with rapidity. A few plain facts, may tend to establish this point, A tree half buried in the earth, *i. e.* laid length-ways along the surface, with the upper half above, and the under half sunk below that surface; it is well known, does not decay all alike. The upper half is speedily consumed. The under part will remain entire for years. The reason of this seems to be, that the former is exposed to all the transitions and alternations above-named; the latter is in a great measure, secluded from them.

A potatoe or an apple, though frosted, may be preserved from the putrid fermentation, for any length of time; if kept continually in the same temperature. But, if either of these, be plunged into tepid water, or exposed to a sudden transition of temperature, it will speedily, or almost instantly, undergo fermentation; and in a very short period, that process will be completed *.

* It is this sudden transition, or change of temperature, that is so destructive to wheat, potatoes, or any other growing crop, during the spring. When these plants are covered with hoar frost in the morning, and the day is bright, and the heat of the sun of course considerable, it occasions such a rapid transition of temperature, that the tender plant is nipt, and speedily decays. Every peasant knows that this is the case. And he must know too, that it is not till the sun shines, and the heat of the day advances, that the leaves of a potatoe, or any other plant, become black and decay.

While the fluids of the plant were frosted during the night, their volume must have been enlarged. It is known, that water, when frozen, occupies a seventh part more space, than it does in a state of fluidity. The fibres being thus expanded, by the watery fluids they

Thus, the alternation of moisture and drought, in a mass of dead vegetables, is favourable to the fermentative process. When any vegetable is kept continually immersed in water, it is not liable to this change so much, as when exposed to this alternation. The trees driven into the dikes in Holland, and the piles used in canals and bridges, which are all constantly kept under water, are preserved entire for ages. For a similar reason, the wood used in coal-pits and other mines, being exposed to an almost uniform temperature, and kept in nearly an equally moist state, is also preserved sound for a long period. If the above reasoning be fair, it follows, that in a climate where the temperature is variable, and the transitions great and rapid, vegetable matter must be most liable to the fermentative process. For the same reason, frequent alternations of wet and dry weather, must promote the same changes. Whereas, if in any climate, the temperature was nearly equable, all the year round, and the degree of moisture always the same; no such changes would be accomplished, and no such process go on. But no such climate exists.

Such are a few of the most remarkable changes

contain; when exposed, on a sudden, to a high temperature, this transition occasions a rapid change in these fluids. They are speedily dissolved, and when the degree of heat is sufficient, they are partly dissipated in gas. In other words, the carbonic acid, and other volatile parts of the vegetable, are evolved in a single day, by the rapidity of the fermentative process. Hence the fetid smell which is uniformly felt, after the sun shines on frosted potatoes, or any other plant in a growing state.

which vegetable matter undergoes, in the medium of the air. And such are the agents employed, to accomplish them. These agents, though simple, are powerful. And when they combine together, and attack any mass of vegetables, nothing can counteract their influence. That is, no vegetable whatever can resist their power. When there is a free access to oxygen, a sufficient degree of moisture and caloric, and, especially, sudden and great transitions of temperature, and of moisture and drought, the hardiest oak that ever adorned the forest, must yield to their influence ; and rapidly tend to dissolution.

In such a medium, therefore, no moss can be formed, of any vegetable matter whatever. The volatile parts, both of ligneous and aquatic plants, must be evolved in gas. The inflammable particles, must be dissipated. The whole mass, therefore, at the completion of the process, must be reduced to vegetable mould; totally disorganized, and not distinguishable from the dust of the earth. If this point be established, it may tend to elucidate, in the clearest manner, the origin and natural history of peat moss. We have, in short, only to advance one step farther, till we attain this end. And if we can point out the changes and combinations, which vegetables undergo, in the medium of water; we may then ascertain distinctly, what peat moss is, and by what chemical process the formation of it is accomplished.

SECTION IV.

Immersed in water, vegetable matter, is not exposed to the irresistible operation, of the agents, above described. Neither ligneous nor aquatic plants of any kind, can, therefore, undergo the above changes; nor form the above combinations in such a medium. It is obvious,

In the *first* place, that they are excluded from the influences of the atmosphere, or the oxygen it contains. Let a congeries of leaves, and twigs, and bark, and trees, such as have been described, in the two first Essays, be huddled together, in the hollow of a wood; and there, overwhelmed in stagnant water; it is clear, that the atmospheric air, can have no access to this mass. The subsequent strata of aquatic plants, that rush up with such rapidity in such situations, it is equally clear, must be placed in a similar state. The conferva, lemna, byssus, sphagnum, &c. &c. which flourish on the surface of such stagnant lakes, while in a growing state, and while they remain at, or near the surface, may be supposed to have access to the air. But it is equally certain, that these plants, in harvest, after the strength of vegetation is over, drop and decay in part. Even those, which continue to vegetate all the year round, become specifically heavier than water, and at that season, (as has been stated) they sink to the bottom. There they are

equally secluded from the atmosphere, as the original mass of ligneous plants, which form the foundation of such a lake.

As vegetables, (and even animal matter, which is more liable to putrescency) while placed in a vacuum, or secluded from the atmosphere, or the oxygen it contains, are not liable to the putrid fermentation; so neither can that process go on, in a mass of vegetables immersed in moss, or in a lake, such as has been described. Whether that moss be in a liquid or solid state, in the form of a watery pulp, or of a compact substance—in either case, vegetable matter buried under it, must be secluded from the influences of the atmosphere.

Secondly, In this situation, there is a superabundance of moisture. And as vegetable matter, when kept continually dry, does not undergo fermentation, so neither can that process be completed, when there is too great a degree of moisture. Especially, where there is no alternation of moisture and drought. In this case, even animal matter, as has been shewn, does not undergo the last stages of that process. It is decomposed by a process very different, and the residuum is possessed of different qualities. A similar difference exists, in the changes and combinations formed by vegetable matter in this medium.

It is true, that a considerable proportion of all vegetables, even of those ligneous plants, which are the most solid and compact, is soluble in water. Box,

oak, and ash, which are among the hardest of all wood, are partly soluble. Dr Watson has established this fact, by a variety of experiments equally simple as satisfactory. "He sunk blocks of the "above species in water, for 110 days. When these "were afterwards removed and dried in the air, they "lost one 32d part of their weight. Mahogany, "walnut, and fir blocks, lost only a 60th part, in "the same period. This clearly proves, that a con-"siderable proportion of such plants, is soluble in "water; though immersed in it only for a short pe-"riod. Had they remained in that medium, for a "longer time; it is certain, that a still greater propor-"tion would have become soluble. In consequence "of these soluble particles being diffused through "the water, in which these plants were steeped, that "liquid was changed both in colour and consistency."

If the hardest, and most compact wood, be partly soluble; it is obvious, that a greater proportion of those plants, which are of a looser texture, and contain little or no ligneous fibre, must be liable to solution in this medium. The juices of many of these vegetables, it is known, may be speedily dissolved in water. The carbonic and gallic acid, and tannin, which they contain, are of this description. Immersed, therefore, in this medium for a course of ages, not only that part which is of easy solution, but all that which is soluble at all, must undergo this chemical operation. The water too, in which they are immersed, must of course, undergo certain

changes. Impregnated with all these soluble particles, it must possess chemical qualities, very distinct from rain or river-water.

But it may be said, that, on this very account, this vegetable matter, according to the hypothesis, suggested, must be in a state of preparation, to form new combinations. This is readily granted. And the greater proportion of that matter that is in a state of solution, the more numerous these combinations must be.

But it does not follow from this, that vegetable matter, though entirely soluble, and even dissolved in water, must therefore undergo, the last stages of the putrid fermentation.

For, *Thirdly*, in such a medium, caloric is as necessary to carry on and complete that process; as in the medium of the atmosphere. In all cases where this process is accomplished, the temperature rises above 60, and sometimes much higher. But till it reach that temperature, there is little or no evolution of gaseous matter, and of course, the process is not complete.

It appears, however, that the vegetable matter in moss, has seldom or never risen, to that temperature. The following facts are stated to shew this:

1. A few feet below the surface of the earth, in all latitudes and climates, the temperature is almost uniformly low. It seldom rises above 48. If it be higher, it must be owing to certain chemical agents, which are not common, to all situations. Hence, most springs are of this temperature.

2. The same is the case in all lakes. "Even in "Italy and Switzerland, Peron found this was the "case. Georgy, Gmelin, Pallas, Leydyard, and "Patrin, observed that the lakes of Siberia, at a cer-"tain depth, were of the same temperature. In "America, Shaw and M'Kenzie found the lakes at "the same depth, no higher in temperature."

3. The ocean too, in all latitudes, whether in the torrid temperature or frigid zones, has been found to be of a low temperature, at a certain depth. "Ir-"vine and Phipps, examined it at 80° north latitude. "Forster did the same, in the opposite hemisphere, "in 64° south. Peron examined it under the equa-"tor. The result of these experiments on this ex-"tended scale was, that at a certain depth, the tem-"perature of the sea was, in all latitudes, nearly the "same, and *uniformly low*."—"In all these cases, "the thermometer sunk, in proportion to the depth, in "which it was placed. Forster found, that Rheamur's "sunk, from 16° to zero; Irvine says that his sunk "two degrees below zero, at the depth of 3900 feet. "The experiments of Ellis and Wallis, Bragley and "Baldh, confirm the above account. The conclusion "is obvious, that in the profound abysses of the "mighty deep, even in the warmest climates, as well "as on the summits of the lofty mountains, a low "temperature uniformly reigns. And as few vege-"tables or land animals can exist in the latter, so "the former are probably destitute of fishes. That

" both are exposed to the most intense perpetual " cold, and perhaps filled with ice."

4. Correspondent to this, the temperature of all the mosses in the world, at the depth of 2 or 3 feet, is almost uniformly low. It seldom exceeds 48. Or if it rise above this, which is very seldom the case, it is owing to certain chemical agents, (which shall afterwards be described) that accidentally combine, with the mass.

If this point be established, we may more distinctly ascertain, what are the chemical changes, which vegetable matter undergoes; in such a medium; and a temperature so low. It is obvious, to demonstration, that there is a want of a sufficient degree of caloric, to carry on and complete the putrid fermentation. That process must be arrested, in its primary stages; owing to the absence of this universal and powerful agent. The volatile particles of that matter, can never assume the gaseous form; or be evolved in a temperature so low.

It cannot be doubted, that the whole elementary principles of the vegetables, may be set free from their former combinations; even in such a medium. In the slow and and silent processes of nature, too, they may combine anew.

The oxygen of the water, may combine with different bases, to form acids. The hydrogen also, may combine, with the carbon; to form oils. And these oils, may form treble combinations, with oxygen, or acids; so as to assume the more concrete form, of bitumens. But none of these simple elementary prin-

ciples, nor the compounds they form, can assume the gaseous state. No evolution of these can, therefore, take place, in such a low temperature.

The residuum, therefore, of vegetable matter in the medium of water, must be very different in its chemical qualities; from that of the same matter, in the medium of the air. In the latter case, it must undergo all the stages of the putrid fermentation; and during that process, the vegetable acids, and oils, and gums, and resins, must disappear. The elementary principles, that are volatile, must escape in the form of gas. In the former medium, and in such a low temperature, no such process can be accomplished; and no such evolution, can take place.

Though the same vegetable acids existed in both, and though the carbonic acid may be formed in the medium of water, as well as in air, yet that acid is not evolved, nor does it assume the gaseous form; till the temperature rises considerably. It is never entirely dissipated; from vegetable matter, till it reach to 80°. The hydrogen and carbon; of vegetable oils, is never discharged, in the form of gas; till the temperature rises as high, or higher, than the latter. As moss seldom or never rises above 48, excepting on the surface, it must, therefore, still possess all these elementary principles; and differ essentially, on this account; from vegetable mould; though it be originally composed of the same materials.

It must be more inflammable, because it contains more hydrogen and carbon. It must be possessed

too, of more acidity, as the vegetable acids have not been expelled. And it must be more tenacious, and insoluble, when dried, in consequence of the combinations formed, by these elementary principles. These are, of course, the very qualities, by which moss is distinguished, from vegetable mould. And these qualities, depend on the medium, and temperature; in which the vegetable matter, has been placed.

If, on the contrary, that matter has, by any means, been exposed to such a high temperature, as is sufficient to make these volatile particles assume the gaseous form, and fly off; and if these have actually been evolved; it is obvious, that this substance must, by this very operation, be deprived of inflammability, and every other quality which distinguishes it from vegetable earth.

This is not all; there is still another agent awanting in such a medium, to accomplish the putrid fermentation.

Fourthly, Whatever be the temperature of moss, it is demonstrable that the vegetable matter immersed in it, is not exposed to the alternations, of moisture and drought, or any of those sudden; or great transitions of temperature; which so powerfully promote, that process. Of this, the reader may satisfy himself, by a simple experiment. Upon examination, he will find, that the temperature of all moss, at the depth of two feet, is not only low, but almost equable all the year round. During the heat of summer, and the cold of winter, it does not vary, above four degrees.

The highest will not be found to be above 50; and the lowest below 46. Deeper in the moss, he will discover little or no variation at all. This low and equable temperature, is equally unfavourable to the putrid fermentation; and it is doubtless one reason, why vegetable matter, converted into moss, retains its distinguishing qualities, inflammability, &c.

It is true indeed, that the surface of all moss is exposed to the alternations, and transitions, of the climate; and all the influences of the atmosphere. But it is equally true, that in all latitudes, where moss is found; it is, on this very account, unfit for fuel. It is never so highly inflammable, as the rest of the mass; which lies deeply immersed. Nay more, it is certain, that in those climates, where a high temperature reigns; or where the above alternations are great and rapid; the surface of the moss is useless to a greater depth, as a fuel; than in colder regions, where such alternations are not so rapid or great. In a low warm sheltered valley, there is a greater depth of surface, deprived in a great degree of inflammability, than on lofty mountains in the immediate vicinity. In the North of France, the surface is more inflammable than in the south. Yet, even in the latter, 15 inches below the surface, moss is found possessed of all its distinguishing qualities.

The reason of this seems to be, that, at the above depth, it is not exposed to the high temperatures of summer, or the sudden transitions of heat and cold,

of the other seasons; which would be sufficient to make the hydrogen, and other volatile particles, assume the form of gas. Therefore the putrid fermentation is not completed, as it is nearly on the surface.

By long exposure to these agents, the peat is robbed of its hydrogen: being saturated with oxygen, it will not admit of a greater doze. In other words, it will burn with difficulty.

This has been doubted by some, and deemed unintelligible by others. Mr Nasmith, in his Essay on Agriculture, lately published, seems to be of this opinion. He judiciously observes, "that every stratum "in moss, must have been the surface of it, at one "time. And he, therefore, very naturally puts the "question, Why is not the whole oxygenated, and "almost incombustible?" To this it may be replied, that it cannot be denied, that the very lowest strata in every moss, must have formed the surface. Yet it seems by no means unaccountable, that this surface should be more oxygenated, than the substrata. While the vegetable matter, which first laid the foundation of the moss, was deeply immersed in water; and the whole assumed the appearance of a lake; that vegetable matter, must have been secluded from the above agents. The manner too, in which the subsequent strata are formed, as described in the second Essay, page 134 shews, that the materials of which they consist, may have been equally secluded. The rapid annual growth of one year, of the confer-

va, lemna, byssus, &c. &c. as soon as they arrive at maturity, become specifically heavier than water; sinking, (as has been shewn they do) to the bottom of the pool, these plants are thereby secluded from the influence of the above agents. At last, however, when the pool is choked full of vegetable matter, and this overtops the water, there it must remain. It cannot sink into the more solid moss, as it did into the liquid pool. Remaining there for ages, exposed to all the above agents; it must undergo, in the medium of the atmosphere, different changes, and form combinations, different from the substrata; which have always been immersed in the medium of water.

This ingenious gentleman makes another remark. He says, "that he has seen surface peat, which, when "cut into small pieces, and thoroughly dried, was "very inflammable; consuming rapidly and emitting "a strong heat."—Of the fact, I do not doubt. Upon examination, however, he will find that the surface of every moss, is less inflammable; than the inferior strata. And that the lowest stratum, bulk for bulk, contains most of this quality. Besides this, the surface of some mosses, may still be so very moist; and covered over with such rich luxuriance of aquatic plants; that these, with the superincumbent water, may seclude that surface, from the above agents; in a great measure. But in every moss which is bare of vegetation, and laid dry, the surface will be found to be almost entirely destitute of inflammability. If this be not the case, it will appear to me somewhat un-

accountable: and I should be happy to hear that such mosses have been carefully examined. One circumstance more may be mentioned, on this point; that the more loose, open and porous the surface of any moss is; it must be deprived of inflammability, by the above means, to a greater depth. On the contrary, such as are solid and compact, and almost as hard as coal, on the surface; must be less exposed to the above agents. It is however certain, that even coal itself, when exposed to them, is, in course of time, stripped of its inflammability, or oxygenated as well as peat.

Hitherto it has only been supposed that vegetable matter is simply immersed in water. It may be added,

Fifthly, That if moss water be possessed of the peculiar qualities, above described, in Section I, if it be possessed of a certain antiseptic power, which preserves vegetable and even animal matter from putrescency, this quality also must be taken into the account. And, by this means, we may more easily ascertain, and account for, the changes which that matter undergoes in this medium.

But the causes and consequences of this distinguishing quality of moss water will come under consideration in the fifth essay. To this may be added one general remark: that, when a mass of vegetable matter, is thus secluded, from the influences of those powerful agents which promote and accomplish, the putrid fermentation; when it is shut up, from access

to the atmosphere, and the oxygen it contains; when it is overcharged with moisture; and never exposed to a sufficient degree of caloric; or those transitions which have been spoken of; that process, cannot be completed.

Even in this medium, and in these circumstances, that matter, must however undergo, certain changes and combinations. To point out these, shall now be my object.

SECTION V.

In general, it is obvious, that in such circumstances, there can be little or no evolution of the volatile particles, of vegetables in a gaseous form. The residuum, therefore, must be very different from that of the same vegetable matter, exposed to the atmosphere; and all the chemical agents, to which it is exposed in that medium.

More particularly,

In the *first* place, less of the carbonic acid which that matter contained, can be evolved, in the medium of water, than that of the atmosphere. In the latter, it has been shewn, that in the ultimate stages of fermentation, that acid is almost entirely expelled. But

it is only in the ultimate stages that this takes place. In the commencement of it no such evolution is accomplished. Nor can it be accomplished till the temperature is raised to a considerable height. From the foregoing statement, it appears that moss or vegetable matter, immersed in water, seldom or never rises to this pitch. Of course, this acid never assumes the gaseous form, on account of the low and equable temperature in which it is placed.

On the contrary, having a strong affinity to water, and being soluble in it, by this means it must be diffused through, and incorporate with, all the mass of vegetable matter that comes into contact with it. It is not insinuated, however, that no farther changes take place. On the contrary, it appears obvious,

Secondly, That the elementary principles of this acid, that is the oxygen and carbon of which it is composed, may be set at liberty. In this case, the latter may be precipitated, or form new combinations.

There appear to me chemical agents sufficient to accomplish such a change, even in this medium. A few of these may be mentioned.

Light has a powerful affinity to oxygen. That affinity is so strong, that some acids, however concentrated, are robbed of a portion of their oxygen when exposed to the light of the sun. If a bottle of oxymuriatic acid be exposed to the light, it lets go a great proportion of the oxygen it contains, and is, by this means, reduced into muriatic acid. That it is the

light, and not the heat of the sun, that accomplishes this change, is obvious from this, that the same acid, if the bottle which contains it be wrapped in black paper, though exposed to the heat of the sun, undergoes no such change. Nay, though heated to a higher temperature in the dark, and though the acid be thereby in part dissipated, even in this case it undergoes no such analysis; that is, the strength of the acid it not thereby reduced, nor is it robbed of its oxygen. What flies off and what remains is still oxymuriatic acid.

It would appear, that the light of the sun operates in the same manner on the surface of mosses and mossy lakes. The carbonic acid contained in them thereby undergoes a similar change. The oxygen is separated, and of course the carbon it held in solution is set free.

In the process of vegetation, similar changes are accomplished. Hence the more carbonic acid which any plant, or the water in which it is immersed, contains, the more oxygen is evolved, when exposed to the light. A plant raised in distilled water emits little. But if the water be impregnated with this acid, oxygen is evolved by the same agent. And, in proportion to the quantity of acid, is the quantity of oxygen emitted. While the carbonic acid is thus stripped of its oxygen, the carbon must be set free; or, more probably, in this case, combine to form the ligneous part of the plant which is placed in the above circumstances.

Hence Senebier found, that a byssus raised in obscurity, contained less carbon or ligneous fibre, than one exposed to the light. In the former case, it yielded only an eighty-ninth part of its weight; whereas, in the latter, it yielded a twenty-fourth part of ligneous fibre.

It appears that similar changes are accomplished, and continually carrying on, in the vast laboratory of nature, with those which Senebier describes in this small scale. The mosses and mossy lakes are all strongly impregnated with carbonic acid. By the rays of the sun, the oxygen it contains being set free, the soluble carbon is of course precipitated. But, as has been hinted already, that carbon being soluble, must enter into new combinations. Uniting with the hydrogen, (which also abounds) to which it has a powerful affinity, it must form a kind of oleaginous inflammable matter. And the fine soft pulpy substance, found at the bottom of such lakes, and so highly inflammable, is probably formed in this manner. Hence it is destitute entirely of organization. Hence Poiret observes, that the carbon it contains is always finely powdered into the smallest particles.

That this process is going on in lakes and marshes, we may learn from the following circumstance. It appears, that aquatic plants, even in a growing state, and immersed in water, are robbed of their oxygen by the light of the sun. It rises, of course, in bubbles to the surface. If a cloud intervene, or night ensue,

this operation ceases *. The quantity, too, of oxygen which they yield, is in proportion to the carbonic acid contained in the water, or the plant, and the length of time to which they are exposed to the light. Senebier shews, that there is a wonderful provision for this purpose. When aquatic plants have discharged oxygen on the surface, they become specifically heavier, and sink in the water. If, again, they are impregnated with carbonic acid, they rise again to the surface, to perform the same operation. By this slow and silent, but certain process of nature, a quantity of soluble carbon must be set free from day to day, and the process, above described, may be carried on with unceasing progress.

Hitherto I have mentioned only the carbonic acid. But a similar change takes place in the gallic. Deyeux has shewn, that the latter is similar, in its composition, to the former. The difference that subsists between them chiefly consists in this, that the gallic contains a greater proportion of carbon than the carbonic acid. When moss, or a mossy lake, therefore, is strongly impregnated with this, a similar process must go on, when it is exposed to the light of the sun. The acid must thereby be decomposed. The oxygen being set free, the carbon may be precipitated in a soluble state, and thus prepared to form similar combinations with those described.

* Dr Smith, in his Introduction to Botany, says, " It is now agreed, " that, in the day-time, plants imbibe, from the atmosphere, carbonic acid " gas; that they decompose it, absorbing the carbon as matter of nour- " ishment, and emitting the oxygen."

If the above account be found to be correct, it must follow, that, in proportion as the water of any moss is more impregnated with the above acid, the process must, in the same proportion, be rapid.

But it may be said, that light can only operate at, or near the surface of such lakes and marshes. It may be added,

Thirdly, That there are chemical agents which may accomplish the same, or similar changes, even at a greater depth. Tennant and Pearson have decomposed the carbonic acid by means of phosphorus. Giobert has done the same by sulphur. These both exist in mosses. The former, as shall be shewn, is not only apparent in all rotting-wood, but visible to the naked eye in many moses. The latter exists in most, and abounds in many, as will appear from the following Essay.

In the decomposition that takes place by the above agents, the carbonic acid, and perhaps the water, is robbed of its oxygen, as it is by the light of the sun. Of course, the carbon must be partly set free. By what process it is done, and what combinations are thereby formed, I do not presume to decide. It is probable, that the oxygen, uniting with these bases, forms the phosphoric and sulphuric acid. The carbon, however, being set free from its former combination, may be precipitated, or thus prepared to combine anew. By this means, a process similar to that which takes place near the surface, may be perpetually advancing, even in the depth of such lakes.

Fourthly, By the above changes and combinations, there must be a constant accession of hydrogen. For, while these aquatic plants discharge oxygen in the light, they greedily absorb and retain hydrogen. Rozier observes, that this is a wonderful provision in nature; by the exhalation of the former, and the absorption of the latter, the air of such mosses is always salubrious.

This is just what might have been expected *à priori*. For, as the carbonic acid is not evolved, on account of the low temperature of the moss, so neither is the hydrogen. By this means, the air is never infected with these deleterious gases.

The fact accords with our expectation, and is a strong corroboration of the above hypothesis. It is universally allowed, that the air of all mosses is highly salubrious, and the inhabitants of such districts healthful.

Carr, in his stranger in Ireland, mentions, that this is the case in that country. Dr Walker makes a similar remark. He says, that " stagnant rain water, " especially in warm weather, occasions, in fenny " countries and carse grounds, intermittent fevers " and putrid diseases: whereas, *no such effects* are " felt from stagnant *moss water*. The moors and " mosses in Scotland, and the turf bogs in Ireland, " are inhabited by as healthy a people as any in the " world. No intermittent fevers, no putrid sore " throats, prevail among them." M. De Luc makes

the same observation. He says, " that over all the " Continent of Europe, which he examined, the air " of the mosses, even in the lowest vallies, is very " salubrious. The inhabitants of these districts are " remarkably healthy. They are not liable to the " fevers and agues which prevail in other low level " lands, in their immediate vicinity, where there are " no mosses."

If the above hypothesis be well founded, the reason of this must be obvious. Little carbonic acid or hydrogen is emitted from moss. On the contrary, the oxygen they discharge must purify the air, and promote the health of those who inhabit such districts *.

That the moisture of mosses, and the evaporation that is occasioned thereby, cools the atmosphere, and may thus be unfavourable to vegetation ; and by de-

* It is not denied that such magazines of moisture generate cold. This, too, by evaporation, must render such districts proportionably cool, even in the heat of summer. For it is well known, that evaporation lowers the temperature of the air. This may be made appear by a simple experiment. Wrap a bottle of wine in a wet cloth, and expose it to a current of air, it will be cooled during the evaporation of the water, several degrees. And the more rapid that evaporation is, the greater degree of cold will be generated. For similar reasons, the more volatile and elastic the fluid that is used, the more intense the cold that is occasioned. The bulb of a thermometer, wet with ardent spirits, cools, and the mercury sinks. With spirit of wine it drops farther. And with ether still more. Hence, a human body, though oppressed with heat, in a warm climate, if covered with a wet cloth, cools. If the cloth be too wet, or wet with any of these volatile spirits, so as to cause a rapid evaporation, the person would perish with cold, even in the heat of summer, or of a warm climate.

scending in hoar-frosts, be the cause of mildews, it is natural to suppose. But, for the same reason, the air of these mosses may be healthful to man. For the low temperature that uniformly reigns in the moss itself, and the comparatively low temperature of the atmosphere, may prevent the exhalation of these noxious gases above described. If, on the contrary, the moss itself were ever raised to that temperature, by which all the superabundant carbonic acid, and hydrogen, &c. it contains, were discharged in a gaseous form, it would not only cease to be moss, that is, an inflammable substance, but during that process it would become a pestilential region, fatal to every living creature.

This leads me to observe another fact, which tallies with, and corroborates the above hypothesis, which is

Fifthly, That in warm climates, where that process goes on with rapidity, no moss is ever formed, though the same materials abound ; and the air is, for the above reason, noxious, and the inhabitants a sickly race of beings. Rozier observes, " that in Bresse " Bressante, the oldest man in a parish does not ex- " ceed fifty years. The bellies of the young are " swelled as with the dropsy. In warm weather, " every visage is of the colour of lead, and they all " appear like walking ghosts."

Dr Jackson, in his account of the fevers that prevail in Jamaica, makes a general remark to the same

effect. He says, "That in warm climates, especially "in the heat of summer, the air of low marshy "lands is pestilential. This he ascribes to the ex-"halation of noxious gases, during the process of "the putrid fermentation. Hence, he observes, that "some districts are healthful in winter and autumn, "which are absolutely pestilential in summer.

"In the low levels of Georgia, the inhabitants "seldom reach the age of fifty. In Peterborough, in "Virginia, the air seems still more deleterious. "There is scarcely one who was born, and has lived "there all his life, above the age of twenty-one. He "says that, in passing through that town, he saw a "native who was then in his twentieth year. Even "this was deemed an advanced age. And he had "all the appearances of it. He was decrepid. And "though he had never been much confined by sick-"ness, yet by breathing constantly the same perni-"cious air, he had arrived at premature old age."

It may be added, that the river Oronooko overflows its banks for nearly six months in the year; that the vapours exhaled by the sun, after the river subsides, corrupt the air, and render one of the richest and most fertile districts in the world, a scene of misery, sickness, and death.

It is sufficient for my purpose, at present, to observe, that in all the above cases, and in every warm climate, the pestilential vapours which prevail, are owing to the rapid fermentation of vegetable and animal matter, and, of course, to the discharge of

carbonic acid and hydrogen from the former, with the addition of azote from the latter. By this means, the atmosphere is vitiated, and proves deleterious.

But unless the temperature be high, no such gases are evolved; no such dangers therefore ensue. During the cold of winter, of course, even some of these regions are healthy.

Now, as moss only exists in the temperate and frigid zones, as it is uniformly in a low temperature, no such consequences can take place. No such deleterious gases are discharged; of course, the air is uniformly healthful *.

* Thus, the beneficence of the great Creator and Preserver of all is conspicuously displayed. Even in those dreary dismal wastes, where nothing but desolation seems to reign, that beneficence may be clearly traced. Were these wild regions utterly destitute of vegetation, or stocked with vegetables of another kind, or exposed to a high temperature, they would become noxious fens. The mighty mass of vegetable matter they contain, by this temperature, would rapidly undergo the putrid fermentation. During that process, it must perpetually have discharged deleterious gases, and become the fatal source of pestilence and disease. As the mighty deep is seasoned with salt, which prevents the waters from putrescency, so the vast regions of the earth, covered with moss and mossy lakes, are, by the same kind Providence, possessed of certain antiseptic powers, and placed in such circumstances as to serve a similar purpose, and promote an end equally beneficent.

To the careless observer, these may appear a useless waste. The enlightened mind must view them in another light. They are the great magazines of heaven, which furnish fuel to those of his creatures, who are placed in climates that stand most in need of it. They are the great laboratory of the universal Lord of all. There, his omniscient eye is fixed, as upon all his other works. There his omnipotent arm may be

Such seem to be the changes and combinations, which vegetable matter undergoes in the medium of water. By these means, the elementary principles of that matter must be set free, and again combine anew. On this account, it is natural to suppose, that, as few or none of these are dissipated in gas, we may expect to find them all in their simple or compound state in moss. To shew what are these simple and compound substances, which might be expected *à priori*, and are really found in peat, shall be the subject of the next Essay. But, before entering on this task, it may be proper to subjoin a few general conclusions, from what has been stated in the foregoing sections.

traced. There, he works with unerring wisdom and unceasing care. Whether such lakes and marshes be placed in the temperate, torrid, or frigid zones, the operation of his hand may be seen in all. New changes and combinations are thereby continually forming, either under the burning rays of the sun, or in the regions of perpetual snow. Though the materials are nearly the same in both, yet they undergo such different modifications in different climates, that they can scarcely be called a homogeneous mass. In a high temperature, the volatile particles of the vegetable matter are dissipated in gas. Where less caloric combines with the mass, *i. e.* in colder or more temperate climes, these particles are not dissipated: but, being separated into their elementary principles, they are prepared to form new combinations, by which peat, pit-coal, and other inflammable matter is prepared, to supply the wants of his creatures. Great and marvellous are all thy works, Lord God Almighty! In wisdom hast thou made them all.

SECTION VI.

GENERAL CONCLUSIONS.

First Conclusion.

If what is stated above be correct, we may ascertain some general data on the formation of peat moss, and assign the reasons why that substance is formed in certain marshes, and not in others, which abound with the same materials. For, if moisture be requisite for the purpose; and if the water must needs be stagnant, and possessed of the antiseptic qualities above described; and if a low and nearly equable temperature be also requisite: it is obvious that neither ligneous nor aquatic plants can undergo the changes and combinations necessary for this purpose, where these requisites are awanting. If, however, there be abundance of moisture, and that be allowed to stagnate, it appears probable that the water must acquire the antiseptic qualities from the vegetables immersed in it; and it seems also probable that the temperature of such a mass, at the depth of a few feet, must be low, and nearly equable. It appears, therefore, that the stagnation of water, in the vegetable matter of which moss is composed, is the chief cause of the formation of that substance: though the antiseptic quality and a low temperature be likewise requisite.

Second Conclusion.

If what has been stated in the first section be correct, if water be absolutely requisite to the formation of moss, and if that water must needs be stagnant, and possessed of an antiseptic quality, we may conclude that we have it in our power to promote or check the process at pleasure. This, if found to be correct, may prove one of the most interesting and important facts that has been stated on this subject. And in whatever point of view we take it, whether in relation to the low-lying mosses that cover our vallies, or to those which lie on the summits of our loftiest mountains, in either case, it is of vast importance to find out the means of promoting or checking the growth of that substance. If the former be situated in such circumstances that they are fit to be converted into a fertile soil, and the latter into an inexhaustible source of fuel to future ages, surely it is unnecessary to press the subject on the public attention.

In the *first* place, if our object be to prevent the growth of moss, all that is necessary, is, to lay it completely dry, or if that cannot be done, to devise means to give the water a current, and prevent it from becoming stagnant; or, even if this be impracticable, to rob it, if possible, of the antiseptic power it possesses. That moss ceases to grow when drained, it is unnecessary to prove. A simple experiment will ascertain the fact. And that experiment it is in the power of any person to make. While moss remains over-

charged with moisture, it is obvious, that the rapid growth and decay of aquatic plants on its surface must annually add to the mass; on the contrary, when drained of moisture, these aquatics will cease to flourish, and of course little addition to the mass of vegetable matter can be made. Findorf accordingly remarks, that wherever any part of the extensive mosses of Duvels moor are laid dry, they cease to grow. It is unnecessary to add that this tallies with every experiment that has been made. Accordingly, it is observed by every person who has brought moss into cultivation, that it subsides, and a piece of ground thus improved is always lower than the moss from which it has been reclaimed. This has been generally ascribed to subsidence *alone*, or to its being robbed of superabuntant moisture; but, on examination, it will be found to be partly, if not *principally*, owing to the annual or perpetual increment of the undrained moss. M. De Luc observes, that the surface of Kedinger moor has risen considerably, within the recollection of the inhabitants. This, he observes, may be partly owing to the swelling of the water contained in it, but chiefly from the formation of new moss on its surface. If any person doubts of this, let him try the experiment. If he dig a pit in this undrained moss, and place a pin, or any mark within an inch of the surface, he will find that this surface has risen sensibly above that mark; whereas, in the drained moss it is otherwise.

If then the object of the proprietor be to prevent

the farther growth of any moss, all that is necessary is to lay it dry. The same simple mean may prevent the original formation of that substance. If any forest be overset, or any accumulation of aquatic plants be accidentally made in any place, if it be carefully drained, and the water prevented from becoming stagnant, no moss will be formed: the whole mass will be converted into mould. If, however, water be allowed to stagnate over such matter, it must, by that very mean, as shall be shewn, acquire antiseptic qualities, calculated to expedite the process, and form that matter into moss. If we regard moss as capable of being converted into a soil, this consideration is of vast importance. But,

Secondly, It is of equal importance if we view it as a fuel. In this case, our great object must be, to prevent moss from being utterly wasted, and to promote its formation or renovation. Yet, it is obvious, that this is equally in our power as to check these processes altogether. For, if water when stagnant, and possessed of antiseptic qualities, promotes the original formation, subsequent increase, and renovation of that substance, in the way above stated, we have it often in our power to accomplish this end. All that is requisite is, that art should lend her feeble aid to the powerful operations of nature, by laying the surface under water, and preventing any current on it.

Where moss lies on lofty mountains, or even 500 or 600 feet above the level of the sea, there is little

prospect of its ever being converted into a soil. It shall be afterwards shewn, in the Seventh Essay, that even in such elevated plains, it may be converted into manure, and conveyed, at a very trifling expence, to lower grounds, where it may be used. But its chief value consists in the fuel which it may furnish to future ages. In all such situations, therefore, it should be dug (and care ought to be taken by every proprietor that it be dug) in pits, so as to secure the renovation of the moss. These pits should be small; they ought also to be left full of water; and no current of fresh or river water ought to be permitted to pass through them. In this case, the moss will certainly be renovated by the growth and decay of aquatic plants, such as have been described in the Second Essay. By this means peats may be dug from the same pits, at least in an age or two, and thus a perpetual supply of valuable fuel may be provided and preserved for future generations.

Where fuel of all kinds is scarce, and little or no coal is found, it is of vast importance to prevent the waste, and promote the renovation of peat moss. The north of Scotland, and the whole kingdom of Ireland, are of this description. In the former, no coal has hitherto been discovered. And in the latter, it is only found in one or two districts. The value of peat, as a fuel, to both these parts of the empire, is great. And it must appear still greater, when it is considered, that there is at present a scarcity, even of that article, in many parts. "Fuel is so dear,"

(says the Marquis of Hertford, in a letter to me) " in " the province of Ulster, that while peat can be got " for that purpose, it cannot be worth any man's " while to employ moss land for the purposes of " agriculture." The same scarcity of fuel seems to be felt in the south as in the north of Ireland. The secretary of the Cork Institution mentions this in one of his letters: " We have no bogs in this county " which we wish to be reclaimed, as they are " barely sufficient for fuel."

To such districts it must be of the greatest importance, not only to prevent the waste of such a valuable article, but to promote the renovation of it as much as possible. In a subsequent essay on peat, as *a fuel*, directions will be given for the first of these purposes; and an account of the various ways by which fuel is prepared in Hanover, Holland, Flanders, and Friezland, as well as in Scotland, England, and Ireland. But in order to promote the last, that is, the renovation of peat mosses when dug, the following hints are submitted. The reader is referred to the second Essay, Sect. II. and III. for a more ample detail.

Means of promoting the renovation of Moss.

1. It ought never to be dug in *forets*, or open casts. For, in this case, when the water is drained off, there is no renovation of moss.

2. It ought always to be dug in pits. And the smaller these pits are, the more rapid is the process

of renovation. In Duvels moor, these pits are six feet wide by twenty feet long. But four feet by eight would serve the purpose better.

3. These pits should never be left dry. The moment the peats are dug, they should be allowed to fill up with moss water. Without this, there can be no renovation of that substance.

4. In digging the pits, care should be taken to leave a little moss in the bottom. In no case ought the subsoil to be laid bare. In every situation where moss is renovated, this rule holds true. The Reverend Dr Skene, Keith, in a letter to me, observes that it is the case in Aberdeenshire. " A moss that is dug in " pits," says he, " is *always* capable of being reno-" vated, if plenty of *water* be kept in it during the " months of July, August, and September, and if it be " not dug to the very *bottom*, which it *never* should " be; for peat moss is like leaven, a little left in the " bottom leavens the rest."

5. When the water is only shallow, *i. e.* about two feet deep, the renovation of moss is more rapid than when it is deeper.

6. No current, of any kind, ought to be allowed to pass through these pits; otherwise it will prevent the commencement of this process, or arrest it, though begun.

7. After the whole moss is pitted, the interstices, or subdivisions, may then be cut into peat. And before this be exhausted, the new formed moss will be ripe, and may be cut in the same manner as formerly.

By following these simple and obvious directions, a moss may be used as a copse-wood, and furnish a perpetual supply of fuel to succeeding ages. The only possible objection to this is, that these pits may prove dangerous to cattle. To prevent this is easy. A large ditch ought to be cut around the whole moss which is allotted for fuel. If this were left nearly full of water, it would serve as a fence; and, by being filled up with new moss, might furnish fuel at a future period.

The rapidity with which moss has been renovated, in certain situations, when the above precautions are used, has been stated in the second Essay. As this has startled some, it may be proper to add, that the author has received much information since the publication of that Essay. From the facts stated, it appears that the renovation of many mosses in Britain is certain, and in some rapid. The ingenious Dr Graham of Aberfoyle, whose accuracy and judgment none will doubt of who know him, mentions a case, which has come under his own eye, in a letter to me. "With regard to the peat holes or pits, which, within these twenty-two years, I have had dug myself, "many of them are already so overgrown with sphagnum, that they present almost a solid substance. "Those that had been dug by one of my predecessors, "between 1732 and 1770, have been long ago renovated: And I have actually had peats from them "again."

If every proprietor in Ireland, and in the north of Scotland, were to restrict his tenants to the above rules, the renovation of moss over all these districts might be promoted, and fuel for future ages, as well the present, might be secured. The subject is highly deserving of the attention not only of individuals, but of all the patriotic societies in the united empire. The Highland Society of Scotland, and the Irish Agricultural Society in particular, ought to take it under their consideration. And the commissioners on the new bill, which the patriotic president of the latter has lately introduced into Parliament, it is hoped, will pay marked attention to the subject.

There may even be situations where the rapid growth of the whole surface of any moss may be promoted by means equally simple. If it be on a level plain, where there is a narrow outlet to the water, which can be stopped up at a small expence, and if that water be allowed to stagnate and overflow the whole; in this case, an inexhaustible fund of fuel, may be secured.

I dwell the longer on this, as it is a point of the greatest importance to the British empire. Though it abounds more with coal than any region of the north of Europe, it is certain that this coal is exhaustible, and it is even supposed by some, that it must be exhausted in the course of a few centuries. Mr Williams has examined the subject with great care, and his observations are formed on the most extensive scale; yet he is decidedly of opinion, that the

rich coal mines of Britain, must, in the course of ages, fail. If so, it is of the highest national importance to preserve our mosses, and promote their renovation and growth, in such elevated situations as have been described.

M. De Luc expresses himself to the same purpose in his letter to me: "Since I read Mr Williams's account of coal-mines in this island, I dread the exhaustion of them more than most people, especially by exportation; peat therefore, must become more and more valuable for fuel. But it certainly requires to be brought into a regular train of cutting, so as not to prevent the renovation of it*."

Third Conclusion.

From the foregoing account of the subject, we may see the reason why moss is never found in warm climates. There the same ligneous and aquatic plants may be accumulated in marshes and lakes; but where the temperature is high, the putrid fermentation, in such a moss, goes on without interruption. The vegetable matter, on the surface of these marshes, must, by this means, be reduced to mould.

* It may be added (though it is foreign to the subject) that if coal be renovated when dug, as well as moss, the utmost exertions ought to be made, to ascertain distinctly what is requisite for this purpose. And if means can be devised to carry on that process, on the most extensive scale, in wasted coal-pits, these means ought instantly to be used. Every proprietor of coal, and the nation at large, is deeply interested in this subject. And, while individuals exert themselves, the legislature ought to interfere, and give liberal encouragement to promote this end.

That moss may be formed on the summits of lofty mountains, or in the depth of lakes and marshes, even in warm climates, cannot be denied. In the former of these situations, the temperature is as low as in colder climates. In the latter, at the depth of five or ten feet in a marsh or lake, the temperature is not only low but equable. But in low vallies, and shallow waters, exposed to a high temperature, and the transitions of the heat and cold of a warm climate, moss cannot exist. Though a quantity of it were transmitted from a colder region, and placed in the above circumstances, it must speedily be reduced to mould, and robbed of inflammability and the other distinguishing qualities of peat. Accordingly, though moss has been discovered in warm climates, like the north of Italy and South America, it has only been found on the summits of the mountains of Peru, and the Alps, Appenines, and Pyrenees. In the adjacent vallies, none can be found.

For the same reason, every moss is less inflammable on the surface than in the inferior strata; and less inflammable in the south of France or England, than in the North. Rozier, who lived for several years near Languedoc, gives a similar account of this. "He "says, that the air in some of the vallies in that vici- "nity is very pestilential. The village of Fontignau, "he thinks, will be totally deserted in half a century. "He ascribes this to the carbonic acid and hydrogen, "which are dissipated in such situations by the *rapid*

"process of putrefaction." And he observes "that "the air becomes more pestilential for years after "these vallies are improved, or turned up to the air, "as that process is thereby expedited: of course, "these deleterious gases are dissipated in greater "abundance."

Fourth Conclusion.

From what is stated in this Essay, we may conclude, that moss and vegetable mould are homogeneous in their origin, however different they may be in their chemical qualities. This difference does not depend so much on the distinct properties of the vegetables of which they are originally composed, as upon the medium in which they have been placed. The very same vegetables which form moss, when immersed in water, will be converted into mould in the medium of the atmosphere. In the latter case, the volatile and inflammable particles of the vegetables are dissipated in gas. In the former no such change is effected. This constitutes, accordingly, the distinguishing difference that subsists between moss and mould. The former, as might have been expected, contains a greater proportion of hydrogen and carbon, and, of course, is more inflammable than the latter.

There is a similar difference between moss and vegetable mould, as between the dust of an animal after putrefaction, and the spermaceti formed of the same matter immersed in water.

In both cases, these substances, however dissimilar, are homogeneous in their origin. In both, the difference that exists between them depends on the medium in which they have been placed. In both, the residuum is highly inflammable, when these substances have been immersed in water and when the putrid fermentation has not been accomplished. In both, that residuum is robbed of its inflammability when that process is completed in the medium of the atmosphere. The organization, too, of both, is totally destroyed in this medium; whereas, in the medium of water, the organization of both animal and vegetable matter is partly preserved after all the changes and combinations it has formed.

This difference may be distinctly ascertained by analysis; that analysis strongly corroborates this conclusion.

In confirmation of this it may be observed, that vegetable mould, inpregnated with petroleum, cannot be distinguished from moss. On the contrary, moss, when robbed of the superabundant hydrogen and carbon, is by this means reduced to vegetable mould.

Fifth Conclusion.

From the above account we may conclude, that moss is vegetable matter which has not yet undergone the putrid fermentation. Mr Aiton, indeed, and Dr Anderson, and even Dr Walker, often speak of peat thoroughly putrified. This appears to me a loose manner of speaking. It seems to be incorrect. If

any peat be thoroughly putrified, it must cease to be inflammable. Yet, according to their account, it is the most inflammable of any species of peat, bulk for bulk. When they speak, therefore, of any moss thoroughly putrid, and yet highly inflammable, they cannot mean, that in any moss that process is completed. For, in the medium in which it is immersed, the great and necessary agents cannot cooperate to effect this change.

That all moss, even the most fibrous, has undergone certain changes, cannot be denied. Hence, it differs, in its chemical qualities, from the recent vegetables of which it consists. That it has been subjected to a process *similar* to the acetous fermentation is probable. By that process the green colour of vegetables is converted into yellow, brown, or red. This is the colour which all the mosses in the world assume, when first dug. Some appear in one shade, others in another, but still they are radically of the same colour.

The dark-coloured compact moss, in which no organization of the original vegetable can be traced, may have led some to conclude that the putrid fermentation has been completed in that species. The decomposition is indeed complete, and the elementary principles of which it is composed, too, may have been as completely separated as if it had been analysed by distillation, or putrefaction. Still it does not follow that the putrid fermentation has been completed. For the great, the necessary agents in

that process, have been awanting. The influences of the atmosphere, and still more, the degree of caloric, and the alternations requisite to carry on and complete this fermentation, have not combined with the moss, or cooperated to effect such a change.

I shall not attempt to define the precise process by which vegetables are converted into moss. It appears to me, however, certain, that it must differ essentially from all the other species of fermentation, that have been described by chemists. And probably it ought to be distinguished by a different name.

Mr Parkinson seems to give a definition of it, which is nearly correct. He calls it "a fermentation peculiar to vegetable matter, placed in such "situations as not only to exclude the external air "and secure the presence of moisture, but to prevent the escape of the more volatile principles, and "which terminates in the formation of those substances called Bitumens."

The above definition seems to be nearly correct. He takes no notice, however, of the absence of *caloric*. Yet this seems to be the key that unlocks the whole mystery. It is on account of the absence of this, that the volatile particles do not escape. It is certain, however, that such a degree of caloric may have been excited (by certain chemical agents) in some mosses, and that these volatile particles may have still been prevented from escaping. Confined by the superincumbent mass of impervious matter, as in a close vessel, or retort, these particles, which would

otherwise have escaped, may have been retained, and combining there anew, may have formed the varieties of bituminous, and resino-bituminous substances found in moss.

Mr Parkinson's definition, in this case, may be correct. But it seems to be a case of rare occurrence. The general cause why these volatile particles remain, and form new combinations, is the absence of caloric.

He seems likewise to be correct in calling this fermentation by a distinct name, viz. the *bituminous*. The appellation is appropriate. For, if each species of fermentation derives its name from the prevailing product which it yields, if that stage in which sugar is produced be called the saccharine, and that in which wine is formed, is called the vinous, and that in which acids are produced is called the acetous,—it appears equally reasonable, and consistent with analogy, to call that peculiar stage in which bitumen is formed, the bituminous fermentation.

Sixth Conclusion.

If moss consists entirely of vegetable matter, and if that matter has undergone the changes and combinations above described, it seems reasonable to conclude that it may be converted both into a soil and a manure, or some other useful purpose. Of whatever description it may be, whether fibrous or compact, whether composed of ligneous or aquatic plants, it is obvious that it may be made subservient to these important purposes. But before it can be turned to

either, it is equally obvious that it must undergo certain changes.

To ascertain correctly what these chemical changes are, and how they may be effected, with most expedition and least expence, *was the sole object in view when I first undertook the investigation of this subject.* All that has hitherto been advanced, however foreign it may at first sight appear, has been advanced with this view. And the whole practical essays on peat moss as a soil and a manure, are directed to this one point, to shew, that, by very simple processes, it may be converted either into the most fertile of all soils, or the richest of manures, or to purposes of equal importance.

Seventh Conclusion.

From the above account of this subject, it appears probable, that we may trace the formation of moss from the commencement to the consummation of the process. This might be a pleasing, perhaps instructive task. It is however a task to which the chemist alone is adequate. I shall not attempt it, but only throw out the following hints.

In the *first* place, the oxygen of the carbonic and gallic acid, being attracted by the light of the sun and other agents, the carbon they held in solution may be thus set at liberty. This carbon has a powerful affinity to hydrogen. Uniting with it, a kind of oily compost may thus be formed. A third combination occasions another change; for when oxygen

combines, it gives this oily compost the concrete form of bitumen. This oxygen may be furnished by the decomposition of the water, or the acids with which it is impregnated. Thus the result of the whole will be a black insoluble compound, destitute of organization, but highly inflammable. The black pulpy moss at the bottom of lakes and marshes, which, by some, has been called perfectly putrid, seems to have been formed by this or a similar process. And this appears to be the first stage.

Secondly, There is another stage in that process, which has arrested my attention. It may be interesting to the reader; I shall, therefore, give a hint of it.

It has been shewn, that aquatic plants promote the formation and renovation of moss. These plants are numerous. Many hundred species of them might be pointed out. In this, however, they *all agree*, that they are *very hardy*, that they contain astringent antiseptic juices, and flourish in water more strongly impregnated with carbonic and gallic acid, than herbaceous plants. By this means, the water in which they grow, must become daily *more* and *more astringent*, as the soluble ingredients of these aquatic plants must be diffused through it.

No doubt, the formation of moss is going on during the growth of such plants, as has been stated in the first stage of the process. As however, those plants, and that water, which contains the *greatest proportion* of the above acids, emit *more oxygen*, and

of course, yield more *soluble carbon*; and, as these acids are continually *accumulating*, by the rapid *growth of such plants*, this process must become proportionably *more rapid*. For, when the waters become *doubly* astringent, they must yield a *double proportion* of materials for the formation of moss in a *given time*.

Thirdly, There is still another stage in this process that claims attention. And, to that stage, all compact moss which was originally a lake, must have arrived. The waters of such a lake, may, or must become, at last, so astringent, and so choked up with the mass of vegetable matter immersed in them, that even aquatics *cease to vegetate*. A variety of changes and combinations must then take place, which must promote the formation of moss, with a *rapidity far beyond any other period*. It might appear presumptuous in me, to attempt to point out what these changes are, or even to venture a conjecture on the subject. I cannot, however, but mention a well-known fact, which, if duly attended to, may throw some light on it.

The fact alluded to is this: that a *dead plant*, thrown into water, occasions a *putrid smell*; whereas, a growing plant, placed in the same water, not only vegetates, but, during this process, it *robs the water of this fetid odour*, and renders it sweet and salubrious. And, though this plant drop in the water, it is not *speedily* decomposed, if *other plants continue to vegetate in the same medium*. By their growth,

they seem thus to communicate an antiseptic quality to the water, which prevents or retards the decomposition of the vegetable matter immersed in it.

May not, or rather, must not the case be similar in mossy lakes? While the aquatic plants continue to vegetate, must not the water be thereby preserved *pure*, and free from *putrescency?* Whereas, when vegetation ceases, must not the vegetable matter *now dead*, be dissolved, and undergo disorganization in a *much shorter period?* Must not *more* soluble carbon and *more* hydrogen thus be set at liberty, by this *decomposition?* And, must not the formation of *moss at this period* be *rapid*, beyond any *former* stage of the *process?*

ESSAY IV.

ESSAY IV.

ON

THE SIMPLE AND COMPOUND SUBSTANCES

THAT

MAY BE EXPECTED,

AND ARE

REALLY FOUND,

IN

PEAT MOSS.

If all moss consists of a congeries of vegetables, placed in such a medium as has been described, and if there has been little evolution of gaseous matter, we may naturally expect to find in it all the component parts of these vegetables. During the maceration to which they are exposed, they must gradually be subjected to disorganization. A process, in some respects similar to analysis, must take place. That process, though slow, may be complete. And a great part of the vegetables must undergo entire disorganization. In this case, the elementary principles of which they were originally composed must be separated, and set free from their former combinations. But, as few of these are evolved in the form of gas, they must enter into new combinations, and form new compounds, which did not exist in the vegetable matter in its recent state.

To point out a *few* of these simple and compound substances that may be expected in moss, is the object of this essay.

SECTION I.

Carbonaceous matter, either in a simple or compound state, may be expected to abound in moss. It exists in every vegetable of which that substance is composed, either in a state of solution or of solidity. In the latter, it forms the fibrous part of every plant, whether ligneous or aquatic. In the former state, it is diffused through all their pores, in the form of vegetable acids, oils and gums.

Ligneous plants, therefore, contain nearly a fifth part of their weight of carbon. Even in aquatics, a considerable proportion exists. In both, it is the same elementary substance. Being nearly incorruptible, it must therefore abound wherever vegetables are decomposed. And where that decomposition is complete, and the organization of that vegetable matter is totally destroyed, as is the case in some kinds of peat, the whole of the carbon of the recent vegetable must be deposited. Though set free from its former combinations, it is not evolved. It must therefore form the chief ingredient of such a moss.

Hydrogen also exists in every vegetable. It con-

stitutes one of the elementary principles of all the essential oils, gums and resins of every plant, whether ligneous or aquatic. Being specifically much lighter than atmospheric air, it is apt to assume the form of gas. In this form, part of the hydrogen of the recent vegetable in moss may have escaped. But, immersed in water, and placed in a low temperature, the proportion that is evolved must be small. By far the greater part must remain.

The whole, however, must be set free from its former combinations, when the vegetable matter is totally decomposed. And these two elementary principles must form new combinations, different from that which existed in the recent vegetable. Having a strong affinity to each other, they must combine to form an oleaginous mass, allied to bitumen. In a subsequent essay it will be shewn, that all the varieties of bituminous matter have been found in moss.

SECTION II.

Sulphur may be expected in moss. All vegetables contain a portion of it. Chaptal accordingly observes, that "wherever vegetable matter is found in "a state of disorganization, sulphur is discovered." In one shape or another, it may, therefore, be expected in moss, *i. e.* either in a state of solution in the water, or incorporated with the moss itself.

Accordingly, most of the springs which issue from mossy grounds are impregnated with it. Many of them are strong chalybeates. Dr Garnet observes, that " Harrowgate waters issue from a mossy bog, " full of rotten wood." It is his opinion, that " all " the sulphur they contain, proceeds from the vege- " table matter." " Sutton bog, near Oxford, Ash- " wood water, and Mechan wells in the county of " Fermanagh, Drumnaver water in Leitrim, Asphaloo " in Tyrone, Owen Brawn near Enniskilling, have " all a similar origin. Dr Rutty says, that they are " all highly impregnated with sulphur and strong " chalybeates."

The waters of such lochs as have a mossy bottom, filled with vegetable matter, shew similar symptoms. This is the case with Loch Neagh and Loch Sneagh. The mud at the bottom of them is a black greasy unctuous substance. It smells remarkably fetid, emits a blue flame when burning, and is strongly impregnated with sulphur. The waters of these lochs are supposed to be medicinal on this account.

Sulphur has been detected in many mosses. Those described by Demoustier, p. 86. of the first Essay, and those in Brabant, mentioned in the same page, are of this description. The strong odour of sulphur which they emit shews this. And in every case where mosses have burst their barriers, such as those mentioned in p. 153 of the second Essay, they have uniformly emitted a similar noisome odour, and shewn symptoms of being impregnated with sulphur.

In the mosses of Picardie it abounds. Bellery in his Memoir, (which obtained the prize from the academy of Amiens in the year 1754) says, that "all "the mosses along the banks of the Somme, contain "a great proportion of sulphur." Dupuget says the same. He adds, that, "when burning, they emit a "sulphureous smell, and the apertures of the moss "are filled with sublimated sulphur." Blavier says, that many of the mosses of Valois are similar to this. "In the districts of Grenoble, and especially on the "mountains of Neure and Vizille, Geroud has point- "ed out many more." Degner says, that sulphur is detected in the Dutch mosses. And De Luc says, that "those of Bremen, and some in North Jutland, "are all of this kind." There can be no doubt, that in many of the British mosses sulphur abounds.

It is not insinuated that every moss contains the same proportion. On the contrary, in some the quantity may be small, in others great. Nor is it asserted, that the whole sulphur detected in any moss, originates from the decomposition of the vegetable matter it contains. Part of it, in some cases, and in others the greater part, may proceed from the subsoil, or from mineral springs. There can be no doubt, however, that sulphur exists in many mosses, and abounds in some.

SECTION III.

Sulphuric acid may, therefore, be expected in such mosses. It is a combination of oxygen and sulphur. How that combination is formed, it may be difficult to ascertain. Whether the sulphur attracts the oxygen contained in the vegetable acids, or whether it occasions a decomposition of the water, and by setting the hydrogen at liberty, and uniting with the oxygen, forms thus the sulphuric acid, it may be difficult to decide. It is certain, however, that this acid has been detected in moss.

The mineral waters that issue from mossy bogs often contain it. "Cross Town water," according to Dr Rutty, "is of this description. Nobber water "in the county of Meath, has a similar source. It "originates from a moss bog, which contains sulphur, "and the spring abounds with sulphuric acid. Kil-"braw water is similar in its origin and qualities."

But if the waters which issue from moss contain the sulphuric acid, it is reasonable to conclude, that this substance itself must also be impregnated with it. Being soluble in water, this acid must be diffused through, and incorporate with the moss. Accordingly, it has been detected in many.

Mr Headrick detected it in the Berkshire and Swinridge-moor mosses, by analysis. The Swedish

mosses, mentioned in the Memoirs of the Royal Academy, seem also to contain it. Lord Meadowbank says, that the moss on his estate contains a proportion of iron, mixed with the sulphuric acid. That which was sent to Dr Black by the Earl of Dalhousie, on analysis was found also to be impregnated with it.

All those which abound in pyrites, or which contain the sulphat of lime, or of magnesia, must have contained a portion of this acid. And it will appear, in a subsequent section, that such mosses abound over Europe.

SECTION IV.

Phosphorus may be expected in moss.

Wherever wood or vegetable matter is decomposed in a moist situation, phosphorus is found. As moss consists of vegetable matter, it may therefore be expected in that substance. A phosphorescent light is accordingly often discovered, when walking over the surface of moss in the dark. To enumerate many instances of this would be superfluous. A few only may be noticed.

Mr Naesmith, in his Essay on Agriculture, says, "I have frequently seen the naked parts of a peat field studded all over with little spangles of wild-fire,

(phosphat of hydrogen,) particularly in stormy weather in autumn." Dr Plott, in his Natural History of Staffordshire, makes a similar remark: "The moors and mosses near Beresford, when trod upon in a dark damp night, emit a bright shining light, like the glow-worm. When a horse's foot breaks through the turf, he seems to fling up fire at every step, which lies shining on the ground, like so many embers. By this means, the track of the horse may be discovered, for nearly a quarter of an hour after he has passed." The mosses of Devonshire exhibit similar appearances. Dr Croon, in a manuscript communicated to the Royal Society, in the year 1665, takes notice of this fact. And some of the mosses in Fife and Ayrshire are phosphorescent.

This luminous appearance is most frequently seen in summer and harvest, seldom in the cold of winter. Mr Boyle observes, that "the light emitted from rotting-wood is nearly extinguished in extreme cold." Dr Priestely thinks, that "the reason of this is, that the cold retards the putrid fermentation." Now, this luminous appearance, so often discovered in moss, is probably owing chiefly to phosphorus, or some modification of that substance. If so, it is a decided proof that moss is not, as Dr Anderson imagined, a living growing vegetable *sui generis*. For no vegetable in a growing state is phosphorescent. Indeed, some land and sea animals are so, even while alive. Some have accordingly ascribed this luminous appearance in moss to these animals. Sir H. Sloan

says, that " on examining this species of earth, sent to him from Ireland, with glasses, he found that it contained a number of small worms." To them he ascribed this phosphorescent appearance.

If, however, phosphorus be the cause of it, as is more probable, it is reasonable to expect, that the phosphoric acid may exist in moss, as well as the sulphuric. For if phosphorus, as has been supposed, decomposes water, even at a low temperature; by this means, the hydrogen being set free, the oxygen may combine with this base to form phosphoric acid.

SECTION V.

Tanin may be expected in moss.

Almost all the ligneous plants, which are detected in it, contain a portion of tanin. The oak, the birch, the alder, and the willow, all abound in tanin. Even the fir-tree is found to contain a proportion of it. It exists in the bark and leaves of all these trees. Heath, too, abounds in tanin. It has even been used, both in the Hebrides and on the Continent, for tanning calves skins.

In some of the aquatic plants, which contribute to the formation of moss, tanin abounds. In the transactions of the Royal Society of Berlin, there is a list

of no less than sixty species of aquatics that have been found fit for the purpose of tanning. Among these the author names the following, which are all found in moss, either in a growing or decayed state: "the Comarum, Lin.: the Tormentilla officinalis: the Myriophyllum: the Equisetum palustre: the Lysimachia lutea, the Vaccinium, the Iris palustre (pseudacorus), the Nymphæa lutea, and Nymphæa alba, &c. &c. are all of this description."

If we consider the immense quantity of ligneous plants of the kinds above enumerated, found in moss, all of them containing tanin in their leaves, boughs and seeds, as well as bark: and that these leaves and seeds have annually dropped for centuries, *i. e.* during the growth and decay of these trees, for one, two, or perhaps three generations; if we consider farther, that, after those forests have been finally overthrown, the whole bark they contained has been blended together in one ruinous mass; and, above all, if we add that, over those ruins, all the above aquatic plants have rushed up with rapidity, and annually accumulated for ages; is it not probable, if not certain, that the mosses of Europe must have contained a very great proportion of tanin?

It is not insinuated, that all the tanin which existed in such a mass of vegetable matter, in its recent state, may now be expected in it, when converted into moss. Being soluble in water, it may partly be washed away. Even oak-bark may be robbed of its tanin, by being frequently diluted in water. If it be

pounded into powder, and if successive portions of water be poured over it, till all the soluble particles are taken up, the liquor last obtained will be nearly destitute of tanin. A similar process may have been carried on in moss. The tanin it contained, in its recent state, being dissolved entirely in water, may be partly washed away.

Nor is it asserted, that tanin may still be detected in moss, in its originally *soluble* and *active* state. It forms insoluble compounds with metallic and other substances. In this case, it cannot be detected without the application of chemical tests. That it has formed such insoluble compounds in moss, is probable, if not certain, from the following experiments. Though moss water yielded no precipitate with glue, yet, when an alkaline solution of moss was made, and the muriat of tin poured into it, a copious precipitation was occassioned. Probably the alkali contributed to occasion this. But the water squeezed out of moss, without the application of alkali, yielded a similar precipitate with the muriat of tin, though not in such a quantity. Such solutions, of a vast variety of mosses, have been tried with the same test, and the result is the same in all. The conclusion is, that tanin exists in all of them, in an *insoluble* state: But, when any chemical agent is applied, which sets the tanin free from this combination, it is instantly detected. The experiment may be easily repeated by the reader. And if it succeed, the conclusion may be made, that the tanin which still exists

in moss, has formed insoluble compounds. In order therefore, to separate it, and restore it to its originally soluble and active state, it is necessary to apply such chemical agents as have been named.

That tanin has existed and operated in almost every moss, at certain periods of its formation, is certain, from the following fact: that all the skins of animals, found buried in it, have uniformly undergone a process similar to tanning. That it has been found in an active state, and operated at very distant periods, is probable from another fact; that bodies have been found in it, which have only been buried for a few years, and others which have lain in it for ages: yet the skins of both have been tanned. That some mosses are still impregnated with tanin, in a soluble and active state, is certain. For, in the Highlands of Scotland, some moss holes are used as tanpits; and in France, moss is used in aid of that process, along with the bark of trees.

There seems reason to conclude, that some mosses may be annually acquiring an accession of tanin; especially, such as lie in the vicinity of an oak-forest, or abound with tormentil, &c. As the tanin exists in the leaves of the oak, and as it is soluble in water, it is reasonable to suppose, that it may be washed down from the declivities of such a forest, and deposited in the low level mosses adjacent. By this means there may be a constant accession of it.

Many mosses, when analysed, are found to contain tanin. And few will be found destitute of it en-

tirely, when chemical tests are applied to them. Pfeiffer attempted to extract tar from peat by a similar process as Lord Dundonald extracted it from coal. The result was the same in the former as in the latter. But along with this tar he found a *styptic juice*, fit for *tanning hides**.

These hints are thrown out, because some have utterly denied that peat contains tanin, and because oak bark is now become extravagantly high in price. If any substitute could be found to supply its place, in part, especially any such substitute as moss, which abounds so much, and is so little valued, it might be a great saving to the nation. A number of experiments on this subject will be detailed in a subsequent Essay.

SECTION VI.

The *gallic acid* may be expected in moss. It is generally found in combination with tanin. All those vegetables which contain the latter, also abound in the former. As most of the ligneous, and many

* Even amber and other bitumens when treated with the sulphuric acid, yield tanin. Coal affords it when treated with the nitric acid. If bituminous matter of the above description, which seem to be the most remote from recent vegetables, yield tanin, it is reasonable to expect, that peat, which is more nearly allied to recent vegetable matter, will yield it if proper tests are used.

of the aquatic plants, are of this description, it is therefore natural to expect, that this acid must have abounded in moss, at the early periods of its formation. Being soluble in water, it must have been diffused through the whole vegetable matter of which the moss is composed. Part of it, too, like the tanin, may have been washed away. And in some cases, especially where calcareous matter incorporates with the moss, this and all the other acids must be neutralized. It cannot, therefore, be always expected in its original active state.

Yet in some mosses it still exists. It has even been found so powerful, as to act on test-paper. Mr Headrick detected it in this state, in the Swinridgemoor moss. Few mosses seem entirely destitute of it. The water squeezed out of them always effervesces with chalk; and, for the most part, yields a dark inky precipitate with the sulphat of iron.

SECTION VII.

Iron may be expected in moss.

Every vegetable contains a portion of this metal. In some it abounds. All solid compact hard wood contains much of it. Fourcroy says, that "nearly one twelfth part of the weight of oak consists of iron." In heath it is still more abundant. Of all vegetables,

indeed, this seems to contain the greatest proportion. As might be expected, the plant flourishes in a sandy ferruginous soil, where few other vegetables can exist. By its rapid growth and decay, such soils are probably supplied with more and more of this metal. The masses of *alios,* found in blocks and strata, are supposed by some to be produced from the growth and decay of this plant.

If iron exists in every plant of which moss is composed, and abounds so much in some, is it not natural to expect a considerable proportion of it in that substance? Being soluble in the acids, may it not thus be diffused through the whole mass of vegetables? Accordingly, we find the oxyd of iron in every moss. And the waters that issue from it are almost uniformly impregnated with more or less of this metal.

By its specific gravity, it must always sink. And the bottom of moss must be expected to contain a greater proportion than the superior strata. When that substance is in a soft pulpy state, the iron will be almost entirely precipitated to the bottom. Probably bog iron ore may be formed in this manner. When the subsoil of moss consists of sand or gravel, the precipitation of iron must, in this case, operate as a cement to such matter. Hence a ferruginous sand and gravel is sometimes found below moss, harder than freestone, and as heavy as ironstone. Some species of vegetables have a more powerful affinity to iron than others. When it is in a state of solution, they must attract it. Hence some trees are dug out

of moss entirely metallified. Though they retain their original organic form, they are entirely converted into iron. Instances of this may be frequently seen in Loch Neagh. Buffon too mentions, that, in digging the ruins of the ancient town of Chatelet, "several iron tools were found, the wooden handles of which were converted into hæmatites. The organization of the wood, however, was entire. These tools are supposed to have been buried 1600 years." Palissey mentions a curious specimen. He says, "that he found part of the root of a vine converted into iron. On examining the subsoil he discovered the cause of this. He found that it contained a considerable portion of vitriol. To this he ascribes the change. Being dissolved in water, the iron, he thought, had been thus incorporated with the root of the plant."

It is almost superfluous to add, that the ashes of peat, in general, are reddish or yellow, and attracted by the magnet; which shews that they contain iron. But it may be proper to observe, that Mr Naismith supposes, that "the iron found in moss is an extraneous matter." He thinks that it is carried thither and deposited by mineral springs. It cannot be doubted that this is partly the case. Probably the greatest proportion, however, proceeds from the disorganization of the vegetable matter of the moss itself.

SECTION VIII.

Calcareous earth may be expected in many mosses. For the most part this must be considered as adventitious matter. The proportion of it which the recent vegetables contain is so small, that it cannot account for the quantity sometimes found in moss. We are, however, at no loss to account for the means by which this extraneous substance may have been deposited in that substance.

Many soils are impregnated with calcareous matter; when they are turned up in the drought of summer, a white efflorescence appears in all the fissures of the earth. This is calcareous matter. The carbonic acid exists in the air, especially on the surface of the earth. It is evolved during the fermentation of the vegetable matter contained in the soil. This acid unites with rain-water, to which liquid it has a powerful affinity. It attracts the particles of calcareous matter, and thus holds them in solution. If any moss therefore be situated on a level plain, in the vicinity of such a soil, the water which washes down the declivities of such lands, must deposit calcareous matter in such low level mosses.

This deposition must still be more copious, where such declivities abound with strata of chalk or limestone. The petrifying springs that issue from such strata, and the rills or rivulets which run over them,

must carry considerable quantities of calcareous matter, at all times, along with them, and deposit it in the vallies, where they become stagnant. Gerard observes, that "this is the process which is perpetually going on in the valley of the Somme. Its banks contain strata of lime-stone; the moss of the valley, of course, is covered over with tufa and calcareous matter." Probably a vast extent of the mosses of Europe are, by the same means, impregnated with calcareous matter. In some situations, a solid lime rock may be formed over the surface of them. Such as lie in the course of such a river as Velino (described in Essay II. page 212) may, by this means, be covered over, in a few years, with a solid encrustation of lime.

Where there are strata of marl in the adjacent declivities, a similar deposition must take place. The shells must be washed down and deposited in the level mosses. Hence it is generally the case, that the same species of shells which exist in such declivities, abound also in the vallies. When fluviatile shells abound in the course of any river, such a deposition must take place wherever that river becomes stagnant. In the drought of summer, the shell-fish always creep down from the banks to the rivulets, in search of nourishment. When a sudden flood occurs, multitudes of them must be washed down. By this means a stratum of adventitious marl may be formed in the vallies. The waters of such rivers, being impregnated with calcareous matter, may form

a cement or encrustation over such a bed of shells, and thus consolidate the whole into marl. By this means, a stratum of it may be formed, either above or under any moss, or even in intermediate strata of it, according to the period at which it is deposited; either prior, or posterior to the moss, or during the time of its formation.

Such mosses as lie along the sea shores, nearly on the same level, or below it, may be covered with strata of calcareous matter, or may contain marine shells under them. By the dashing of the waves, during the impetuosity of the storm, in high tides, a vast quantity of sea sand and broken shells may be thrown over the surface of such mosses. Dr Walker observes, that this is the case along the western shores of the Highlands of Scotland, and the Hebrides. "There the mossy soil is contiguous to flood-mark. The blowing sand on the beach is carried a considerable way into the moss. The particles of this sand are very small; it consists in a great measure of pulverised shells." The subsoil of many mosses consists of a similar sand; and below this another stratum of moss is discovered. This is the case along the coast of Holland.

All this calcareous matter may be adventitious; it did not exist in the moss till after its formation. But there are cases in which such matter must have been formed on the very spot which the mosses now occupy, either prior to, or during the period of their formation.

All such as have, at one period, been lakes, or extensive marshes filled with reeds, are of this description. In mossy lakes, shell-fish sometimes abound. They are frequently found alive. This is the case with those which the Earl of Cromarty describes,—see Essay II. p. 213. At other times the fish are all dead. The shells which contained them, when alive in the lake, are deposited in the bottom, and converted into a stratum of marl below the moss. Innumerable instances of this may be pointed out over all Europe.

Bomare observes, that marl frequently forms the subsoil of moss in France. Professor Stewart of Dublin says, that the same is the case with the Irish bogs. He was appointed to make a survey of the kingdom by the Dublin Society. The result of his researches after marl and lime he politely communicated to me, in the following words: "Marl abounds in Ireland. I discovered this most valuable manure in every county, excepting Mayo, where I was not. It is found in the bottom of the Irish bogs, from six inches to as many feet, in the moss. In some hollow bogs the strata are nine and ten feet thick." Many of the English mosses have a similar subsoil, especially in Cumberland. The ingenious Sir James Hall, Bart. of Dunglass, in a letter to me, observes, "in this estate, marl forms the subsoil of moss. I conceive it to be the result of a petrifying spring. But the existence of shell-marl in the subsoil of moss is extremely common. Indeed it is almost universal

in those mosses which lie in low countries, surrounded by fertile lands." In all the three Lothians many of this description are found. I have seen a number myself. Mr Lochhead* takes notice that this is the case in the mosses of Dumfries-shire. "These lie in narrow contracted dales. It is obvious that they have been originally lakes. Shells of fresh-water fish are found in immense quantities, forming a complete stratum of marl at the bottom of the moss. The stratification of these mosses deserves to be noticed. It shews the manner in which they have been formed. The lowest strata consist of plants which flourish under water. The next above these, contains such plants as emerge partly out of the water when growing. The third tier consists of such as flourish in the air, with their roots only in water. The varieties of the musci appear on the surface, and constitute the highest stratum. Below all these lies the marl." There can be no doubt in this case that the marl was formed while this dale was a lake. In other instances that might be named, the marl intervenes between the strata of moss. In this case it has been formed, most probably, when the whole appeared as a morass, filled with reeds and rushes. There the shell-fish must have been formed; and at that period must they have been deposited.

* The Natural History Society in Edinburgh, with a politeness that lays me under strong obligations, permitted me to peruse his MS. essay in their records. The extracts made from it are all ascribed to the ingenious author, and marked as quotations.

The stratum of moss that appears above the marl, in this case, must have been formed at a subsequent period.

Besides calcareous earth, other extraneous matter may be expected in moss. *Sand* and *clay* may be washed down from the declivities and deposited in mossy vallies. Sometimes these may be diffused through the whole moss, and at other times form distinct strata, either on the surface, or in intermediate layers. In extensive levels, through which large rivers run, and especially near the mouths of such rivers, this must be the case. Accordingly, M. De Luc mentions, that in "digging a well, near Amsterdam, in 1605, the following strata were laid open: fifty-one feet on the surface was sand, mixed with moss and clay. The sand and clay were of the same quality with those which exist on the high grounds, over which the rivers run."

In the vicinity of Rotterdam, a similar stratum is described by the same author: "twenty feet on the surface was found to consist of moss, mixed with much clay."

SECTION IX.

Fixed alkalies may be expected in some mosses.

Many of the ligneous plants, and some of the aquatics of which moss is composed, contain potass

when burnt. It might be expected that they would yield a small proportion of it, even though immersed in water, and in the form of peat moss*. That proportion, however, must, in all cases, be smaller than the same vegetables contained in their recent state. For when this alkali must have been in a state of solution, it may be partly washed away, or blended so much with the mass of heterogeneous matter, as almost to disappear, or be neutralized altogether. The vegetable acids, which are held in solution in all moss water, and the mineral acids which exist in some, must render the alkali of the vegetable matter almost entirely effete. There are some salts formed in moss, too, which cannot co-exist with potass. Hence, wood long immersed in water yields little of it when burnt. Mr Hatchett discovered none in the ashes of Bovey coal, or the leaves of the Iceland schistus.

Yet in moss wood a portion of potass may sometimes be detected in an active state. That same accurate chemist found, that "the ashes of the submerged forest of Sutton, on the coast of Lincoln, contained potass." And he makes this general remark, "that wood, however long submerged, is not deprived of alkali, unless it has been more or less converted into coal." Whether the bituminous oil may neutralize the alkali in this case, it is not said. Ribaucourt expressly asserts, that potass, in greater or

* Such mosses as have been originally formed of the ruins of a forest consumed by fire, must have contained a very considerable proportion of potass at the period of their formation.

less quantities, may be extracted from the ashes of peat.

Soda, the other fixed alkali, may be expected in some mosses. All such as lie below the level of the sea, or have originally been salt lakes, are of this description. The Darry, or Braak Torf of the Dutch, and all those mosses along the coasts of Holland and Britain and France, which contain sea salt, are of this description also. Accordingly, soda has been detected in the mosses of Picardy. And if those which are found below the level of the sea in the coasts of Lincoln, Cornwall, Cumberland, Wales, and the western isles of Scotland, were analysed in the same manner, as the mosses of Picardy have been, soda might be detected in them. The quantity must be great or small in proportion to the quantity of sea salt they contain. Mr Sommerville, in his Essay on Manures, says, " that the proportion of alkali found in moss is from a 22d to a 23d part of its weight." If any of the above mosses yield even the smallest proportion which he points out, they must be of great value, especially as a manure.

SECTION X.

Volatile alkali.

Peat, and all the varieties of bituminous matter, yield it on distillation. It may be extracted from the former in great abundance. Blavier has made the

experiment. The result of it was such, that he gives it as his decided opinion, "that the distillation of peat may supply the place of the distillation of animal matter to great advantage, for forming sal ammonia for economical purposes *." The volatile alkali is probably formed during the distillation of peat in this case. Yet, unless that substance contained hydrogen and azote, the elementary principles of which this alkali is composed, it would not be formed.

When the water is squeezed out of moss and poured over unslaked lime, abundance of volatile alkali is discharged. As it consists of hydrogen and *azote*, and as few vegetables contain the latter, it has been matter of surprise to some that this substance should exist in peat. Mr Hatchett takes particular notice of this. The chief difficulty seems to be, to discover the origin of that proportion of azote, which is requisite to form such a quantity of volatile alkali as exists in moss. To obviate this difficulty, the following remarks are offered.

Though few vegetables contain azote, in some it abounds. Most of the fungi are of this description; and these abound in situations similar to moss. Wherever wood is suffered to decay in a damp situation, a variety of the fungi may be found.

But it is not to this source chiefly that we must trace the origin of azote. The quantity which these

* The manner of extracting it by distillation will be described in a subsequent Essay.

vegetables may be supposed to yield, is not adequate to account for the vast proportion of volatile alkali found in moss. In all probability, the greatest proportion of azote proceeds from animal matter deposited in it. It may be said that no animal, in a living state, is detected in moss; and that the skeletons that are found are so few, that they by no means account for the quantity of azote necessary for the purpose.

Let it, however, be recollected, that most of these mosses have existed—first, in the form of stately forests; secondly, of extended lakes; and lastly, in that of marshes. In all these stages of their formation, an immense quantity of animal matter must have been deposited in them.

1. When mosses existed in the state of extensive forests, all the variety of wild beasts must have roamed at large through them. There, too, they must have died, and been deposited among the ruins and rubbish of vegetable matter. Hence, the skeletons of the elk, the rein-deer, and every wild animal, have been dug out of mosses, in every quarter of Europe where that substance exists.

At a subsequent and more civilized period, these extensive forests, which appear now as barren mosses, furnished pasture for domesticated animals. Mr Chalmers, in his Caledonia, has proved, from authentic records, "that many of the mosses of Scotland were extended forests in the twelfth and thirteenth centuries. At that period, too, he has shewn, that they afforded rich pasture for all kinds of cattle.

Horses and swine, and horned cattle, were all reared in abundance in these woods. There many of them must have perished, and been deposited amid the ruins of the forests *. Hence, the bones of all *kinds* of animals of this description have been dug out of moss. In sinking a pit near Dulverton, in Somersetshire, many pigs were discovered, in various postures. Their shape was entire; and the hair remained on their skin, which had assumed a dry membranous appearance.

The whole animal matter that belonged to these skeletons, most probably has been deposited along with them. Besides these larger animals, all the variety of birds and reptiles, and innumerable insects that frequented such regions, must have furnished a considerable proportion of animal matter.

2. Many mosses have, at one period, been extensive lakes. Fishes of various kinds must have abounded in them. Even after aquatic reeds and other plants had partly filled up these lakes, some species of fish may have existed in them. And when they were entirely filled up with these plants, the whole of these fishes must have perished, and been deposited on the spot. Hence skeletons, of a very large size,

* The mineral tallow, found in some mosses, most probably owes its origin to such animals. Dr Walker supposed it to be the "remains of the bugle. The tallow being valuable, he thinks it may have been dropped by accident, or deposited in moss by design, and neglected." Perhaps the domesticated animals above-described, as well as the wild beasts, may have furnished material for this substance. Being deposited, they may have been converted into a kind of spermaceti.

have been dug out of moss. Dugdale, in his history of draining and embanking, says, that the "skeleton of a fish, nearly twenty feet long, was discovered by Sir R. Cotton, at the skirt of Connington Downs, in Huntingtonshire, six feet below the surface of the earth."

3. Many mosses, at one period, have been filled with reeds, and been impassable morasses. Shell-fish must have abounded in such situations. The vast quantity of the various strata of shell-marl, found above or below, or in the intervening strata of moss, are sufficient evidence of this.

There are, besides, various quadrupeds of the largest size, that frequent such morasses in every quarter of the globe. The skeletons of these, of all sizes, and every variety, from the mammoth to the meanest animal, are accordingly discovered, often in immense quantities, over the vast empire of Russia, and the extensive continent of America, where such morasses abound.

Though, therefore, no living creature be now detected in moss, when it is fully formed, yet, as such an immense variety must have existed, during the different periods of its formation, whether in the state of a forest, a lake, or morass, we may, by this means, account for the proportion of azote, which has contributed to the formation of volatile alkali. The vegetable matter it contains may have furnished a sufficient quantity of hydrogen. And the variety of beasts of the field, fishes, fowls, and insects, deposited in that vege-

table matter, may have furnished azote. It will therefore appear less surprising, that all moss yields volatile alkali by distillation, and some a great quantity.

SECTION XI.

A VARIETY of *saline substances* may be expected in moss.

The bases of many salts are discovered in that substance. Iron, lime, magnesia, soda, potass, and volatile alkali, according to the foregoing account, have been detected in it. A variety of the acids have also been discovered in that substance. By the combination of these acids with the above bases, a variety of salts must be formed.

It is not reasonable to expect the same salts in every moss, nor the same proportion of any one of them in any. One moss which contains one basis, and abounds in one acid, must abound in one species, and another in another, according to the different bases and acids it contains. Of all the salts hitherto detected in that substance, the most common are those formed by the sulphuric acid and the above bases.

The Sulphats.

1. The sulphat of iron may be expected in all those mosses in which the sulphuric acid is found.

Hence, Dupuget detected this salt in the peat of Picardie, in the valley of the Somme. He says, that it abounds with pyrites. Roland de la Platiere discovered it also in the mosses of Beauvois. Blavier says that the mosses of Valois are pyritous. Giroud has pointed out many of the same description, in the district of Grenoble, especially on the mountains of Neure and Vizille. A brass-coloured earth of pyrites has been found in the Dutch mosses by Degner. And De Luc says, that those of Bremen are pyritous. The Swedish mosses seem to be similar. "When newly dug, the peat is covered with a white efflorescent salt, of the appearance of a white powder. This is found to be the sulphat of iron. It is, of course, of a very styptic and astringent taste." Some of the Russian mosses yield a similar salt. Professor Robison says, that he saw "three places in Russia, where there is superficial peat moss. In all of these, vitriol is so abundant as to effloresce. One, in particular, near Petersburgh, shews it every morning, when the dew has dried up." Mr Headrick discovered this salt in the Berkshire and Swinridge-moor peat by analysis. And there can be no doubt that many of the Scotish mosses are of the same description. That which was sent to Dr Black, by the Earl of Dalhousie, is certainly so. "It was a thick mass, taken wet from the surface, with a little grass on it. The lowest part of it was black and peaty. The Doctor found that it contained a strong vitriolic liquor, such as is afforded by the vitriolization of

pyrites. He extracted this by water, and found that it contained very good crystallized vitriol, amounting nearly to two ounces from the pound weight of peat." Lord Meadowbank says, that his peat contains sulphuric acid, united with iron. Degner says, that some of the Dutch mosses yield one ounce per pound, others only half that quantity of this salt.

This subject is of considerable importance. Many mosses may be found to contain such a proportion of this salt, that vitriol may be extracted from them with equal success, and much more economy than from the pyrites of coal-mines. Some of the French mosses are of this description. Dumain describes one, which Du Hamel analysed. Three pounds weight of this peat yielded 16 oz. of copperas *.

Vitriol, of course, is formed, by a very simple and economical process, from the mosses of Picardie and Beauvois. And there can be little doubt, that some of the most barren mosses of Britain may serve the same purpose.

2. The sulphat of lime or gypsum may be expected in all such mosses as contain calcareous matter and sulphuric acid. Mr Nasmith detected this salt in the peat which he describes. And Mr Headrick found it in the Berkshire and Swinridge-moor

* The quantity of this salt, deposited on the surface of such mosses as have spontaneously taken fire, must be great indeed. Especially if that conflagration has been occasioned by the pyrites they contained, which is very probable.

mosses. Even the soft, foggy, yellow peat, contained a portion of gypsum, but no iron.

3. Magnesia forms a salt with the sulphuric acid. It may therefore be expected in such mosses as abound with this acid and sea salt. In Berkshire peat, a considerable proportion of the sulphat of magnesia or Epsom salt, was detected by Mr Headrick, and a smaller quantity in Swinridge-moor. Mr Nasmith discovered the same salt in moss, thirty miles distant from the sea.

4. For the same reason, the sulphat of soda may be expected in mosses of the above description. Le Sage detected this salt in the Dutch mosses. It has also been discovered in those of Picardie, in the valley of the Somme. Ribaucourt discovered it in other mosses.

5. As volatile alkali exists in almost every moss, the sulphat of ammonia may be expected in all such as contain the sulphuric acid. Blavier extracted this salt from many of the French mosses.

The above salts are by far the most frequent and the most abundant in peat. They are all formed of the sulphuric acid and the above bases. But as other acids exists in moss, other salts may also be formed of the same bases. A few only of these shall be named.

Muriats.

The muriatic acid exists in all those mosses which have originally been salt lakes, or arms of

the sea, or, at a subsequent period, overwhelmed by it.

1. The muriat of sòda, or common sea salt, may be therefore expected in all such.

2. The muriat of lime may also be detected in them, if they contain calcareous matter.

Carbonats.

The carbonic acid exists in moss. Combining with the above basis, it must form different salts.

1. The carbonate of iron may be expected in some mosses.

2. The carbonate of lime may exist in others.

Gallats.

The gallic acid in moss may also combine with the above bases, especially with iron.

1. The gallat of iron, therefore, abounds in some. Hence the dark black inky colour they assume. And hence they are used for dying wool, wood, and ivory.

It is not meant to be affirmed, that all the above salts are formed of the materials originally found in moss. Part of them may be adventitious. It may proceed from the subsoil or mineral springs. That subsoil, of course, generally contains similar salts with those discovered in the moss itself.

Many of these substances, and most of these salts, are detected in coal and other bituminous substances. There is in this, and many other respects,

an obvious alliance between them and peat moss. That alliance is an interesting subject in geology; by tracing it, we may probably illustrate the origin and natural history of all these substances.

This is reserved as the subject of the following Essay.

ESSAY V.

ESSAY V.

ON
THE ALLIANCE BETWEEN
PEAT MOSS
AND
SURTURBRANDT, COAL, AND JET.

The sum of the foregoing Essays, and the general conclusion from the facts stated in them, is, that all peat moss is of vegetable origin. The general argument on which this conclusion rests, is, that vegetable matter, in its original organized state, may be detected in that substance.

On the surface of moss, the organization of the plants of which it is composed is often entire. That organization becomes fainter and fainter, as we dig down to the bottom, where it almost, or altogether disappears. Though few substances are more dissimilar in appearance, than the fibrous moss on the surface, and the solid black peat dug out from the bottom, this is no proof that they are of different origin. On the contrary, as the former is obviously and altogether composed of vegetable matter, it appears reasonable to conclude, that the latter may be traced to the same source; more especially, as the most compact peat, when diluted in water, and examined by a microscope, discovers the most distinct traces

of its fibrous texture. Though the origin of the latter appeared doubtful, as that of the former is decisive, it appears more reasonable to ascribe both to this source, than the one to vegetable, and the other to mineral origin.

Geologists, in every other case, reason from analogy. They explain the obscure by the luminous, and the doubtful by the decisive. This is particularly the case in calcareous matter of all kinds. In general, it contains the remains of the organized kingdoms of nature. In many cases, the organization of animal matter, is as entire in limestone and marl, as that of vegetable is in the most fibrous peat. Marl, for instance, not only always contains the shells of testaceous animals, but some species of that substance seems to be composed of nothing else. The precise form of the original shell, and the most delicate and minute organization of every part of it, is as entire as in its recent state. The species to which it belongs may be as clearly ascertained as the different vegetables of which some moss is composed. And, as some of these vegetables are discovered in the latter, still in a growing state, so shells have been found in the former, containing living animals in them, even after the mass is partly consolidated into marl.

And as there is a regular gradation in moss, from a state of organization on the surface, till it becomes altogether evanescent at the bottom, so there is a similar gradation in this species of calcareous matter. In chalky marl, for instance, the shells are often pre-

served entire. In that which is impregnated with siliceous matter, they are often covered over with a siliceous paste, like a coat of mail. In other cases, the calcareous matter of the shell is corroded, and a void is left which it once occupied ; that void, however, is of the precise form and dimensions of the original shell, and contains the most correct impressions of it. In other species, the shells are broken and crumbled down into powder or paste, where only a few, and sometimes none, can be detected in an organized state.

In the varieties of limestone, a similar gradation may be traced as in peat moss and marl. Some lime seems to be entirely composed of shells. In other cases, there is a gradual progressive disorganization, till not one vestige of organized matter can be detected ; the whole mass appears as a solid compact homogeneous rock. The difference between marl and limestone, containing shells in a distinct state of organization, and those which are entirely destitute of it, is as great as between the most fibrous and the most compact moss. Yet no one doubts that all these varieties of marl are homogeneous, and of the same origin. And it would be deemed inconsistent with analogy, to ascribe the one to animal, and the other to mineral origin.

To adopt the language of that celebrated geologist, Dr Hutton : " If one cockle-shell, or piece of coral, be found in a mass of limestone, on the top of the Alps or Andes, it must be concluded, that this bed

of stone has been originally formed at the bottom of the sea, as much as another which is evidently composed *altogether* of coral or shells."

The analogy is equally, if not more conclusive, as to every species of peat moss. If vegetable matter be detected, even in the most compact peat, in a distinct state of organization, it is as reasonable to conclude that this species is of vegetable origin, as the most fibrous peat, in which every plant of which it is composed may be found in its original organic form.

But if this position be well founded, and if this analogical reasoning be conclusive, it may be pursued much farther than in *peat moss.* For surturbrandt, coal, and even jet, often contain vegetable matter in an organized state. We may, therefore, on this account, trace them to the same source. In these substances, indeed, the traces of vegetable matter are fewer, and less decisive. But this is what might have been expected *à priori* ; for peat is obviously of more recent origin than any one of these substances : the records of its origin and natural history must therefore be better preserved. The records of the other bituminous substances mentioned, must be lost in the lapse of time. Like the civil history of all nations, so the natural history of these substances, at the remote period of their first formation, must be partly fabulous. Only a few scattered fragments can be found ; even these, as might be expected,

must be impaired amid the wreck and ruins of remote ages.

Yet there are still left a few precious relics, still legible, and still entire. Though, when scattered, and considered separately, they afford no decisive evidence of the origin of these substances, yet, in proportion as they are collected in greater number, and collated with more care, that evidence becomes more and more decisive and clear; and when the whole are taken together, in one unbroken series, that evidence becomes nearly irresistible.

The sole object of this essay is to collect facts and collate them together, and to shew to what conclusions they naturally lead. "Accumulated facts," says the illustrious Bacon, "and attentive observation alone, can imprint on any hypothesis the sacred seal of truth." To that tribunal alone the author appeals. Geologists must judge for themselves of the justice of the general conclusions he attempts to draw from them. These conclusions he values little. The facts contained in the following essay may be valuable, especially to such as may be qualified to discuss the subject. The general hypothesis suggested in the following pages *is*, *that there is a clear and decided alliance* between peat, surturbrandt, coal, and jet.

If it can be shewn, I. That similar vegetables may be detected in the latter, in an organized state, as in the former;

II. If there appears to be the same gradual disorganization of that vegetable matter in both;

III. If the softest peat can be converted into a substance scarcely distinguishable from coal; the alliance between peat, surturbrandt, coal, and jet, will appear more obvious. And the origin of all these substances may perhaps be more clearly elucidated.

With this view, the following facts are submitted on each of these distinct subjects. As surturbrandt, or Bovey coal, seems to bear the nearest alliance to peat moss, it may be considered first in order.

SECTION I.

*Of the Alliance between Peat Moss, Surturbrandt, and Bovey Coal**.

THESE substances certainly constitute a species of matter different from peat moss. They have, therefore, generally been supposed to be of mineral origin. The alliance between them and peat, (as far as the author knows) has never been distinctly traced. Some distinguished authors seem even to doubt of

* Perhaps the submarine forests along the coast of Lincolnshire and elsewhere, might have been considered as an intermediate gradation between peat and Bovey coal. They might have therefore furnished the subject of a distinct section. These forests, however, seem to be, in all respects, so homogeneous to peat moss, that it appears unnecessary to consider them as constituting a species of matter distinct from it.

this alliance. The ingenious M. De Luc, in his letter to me in November 1807, seems to be of this opinion. His words are: "You place Bovey coal among the products of resinous wood. I was impressed with the same idea, from some specimens which I have seen. But having been last summer on the spot, the sight of the layers made me change my opinion. I could see in them nothing but strata of bituminous clay. For if it were wood, it must be sawed planks, laid over one another; and planks too in length of the whole extent of the strata, without any discontinuation but by fractures. Therefore it cannot be wood. I communicate this remark to you for your consideration. But as I have met with people who have also been on the spot, and entertain a different opinion, it is not impossible but I may again go to see it next summer, and, in that case, I will give it more attention."

Other authors have supposed that Bovey coal belongs partly to the mineral and partly to the vegetable kingdom. Brochant, in his Mineralogy, seems to maintain this opinion. He says, that "it is half mineral and half vegetable." And he adds, that "Waller calls it *vegetabile fossile bituminosum.*"

Brongniart thinks that "it is more a vegetable than a mineral substance." He observes, "that it ought not to form a variety in the system of minerals, if it did not, by insensible degrees, graduate into those varieties which precede and follow it."

This insensible gradation is one of the most inte-

resting and curious subjects in geology; but it appears to be *no conclusive argument against the vegetable origin of Bovey coal.* On the contrary, as the same gradation may be observed in peat moss, it seems to corroborate this conclusion. As the colours of the rainbow, though distinct, graduate into each other by such beautifully delicate, and so insensible shades, that it is impossible to say where one colour commences, or another ends; so there seems to be a similar gradation in all the kingdoms of nature. That gradation has been hinted at in calcareous matter; but it is equally conspicuous between the vegetable, the mineral, and animal kingdoms. These graduate into each other by shades equally delicate and imperceptible; so that it is difficult, if not impossible, to fix the limits between them, or to say,—at this point the one begins, and the other ends. There are animals which can scarcely be distinguished, by their habitudes, from vegetables; and there are vegetables which bear such a resemblance, in every respect, to minerals, that it is extremely difficult to say to which class they belong.

On this account, it may be interesting, and probably tend to elucidate the subject, if we trace the alliance between peat moss and Bovey coal; especially as the former is decidedly of vegetable origin, and the latter has been supposed to belong to the mineral kingdom. And if this alliance can be traced, step by step, through coal, jet, and other bituminous substances, the subject must appear still more interest-

ing, and the natural history of all of them may perhaps appear in a clearer point of view.

There are many obvious advantages to be obtained by following this method. We may thereby trace the various *intermediate links* which unite the *extremes* of the chain; and, by following the analogy between them, we may arrive at more certain conclusions. Whereas, if we were only to look at the two extremes *separately*, this analogy would be lost, at least it could not be so clearly traced. For instance, soft fibrous peat, one of these extremes, is so obviously and so nearly allied to the vegetable kingdom, and so unlike coal and jet, that, without surveying the intermediate links, the alliance between them could not be traced. Coal and jet, the other extreme, are so completely bituminated, and the vegetable fibre is in general so entirely destroyed, that we are equally at a loss, in viewing these alone, to trace their alliance to the vegetable kingdom. Whereas, if we carefully examine the *intermediate* links which unite these extremes, we may, step by step, by a slow but sure path, arrive at clear conclusions, not only as to the alliance that exists between all of them, but as to the origin of each.

Bovey coal seems only to be advanced one step farther than compact peat, in the process of bituminization. The former often bears more evident traces of vegetable origin than the latter. In the former, these traces are frequently so palpable and so obvious, that they can be clearly seen by the naked

eye; in the latter, the organization of the vegetables of which it is composed, is sometimes so entirely gone, that it can only be detected by the aid of a microscope.

This, however, is not always the case. In some specimens of Bovey coal there are no traces of vegetable organization, though in others they are obvious and entire. Werner accordingly supposed that there were two distinct species of that substance. Brochant, however, observes, "that they are linked together by such an insensible gradation, that the one is only a modification of the other." In this respect there is a *general alliance* between peat and Bovey coal. In both there is the same gradation, and in both the same difference. Compact moss bears the same resemblance to fibrous, as Bovey coal with organized vegetables in it bears to that which contains no vestige of organization. But this alliance may be traced still more clearly. For if it can be shewn that wood is detected in Bovey coal, in its original organic form; if all the different parts of ligneous plants, such as the roots, and stems, and branches, and bark, and leaves, and fruits, be detected in Bovey coal as well as peat; still more, if part of the same tree has been discovered in its original state, and another part converted into Bovey coal; and if similar aquatic as well as ligneous plants have been discovered in each of these substances, the alliance that subsists between them must appear obvious.

To establish this alliance, and illustrate the origin

of both these substances, the following facts are suggested.

First, The wood of which surturbrandt seems to be composed is often, if not generally, found in its original organic form. It is, however, always flattened or compressed in a greater or less degree, and seldom or never in the circular form of the trunk of a tree. The annular rings, however, which mark the growth of the original plant, may often be traced. These always assume the elliptical form; this may be owing partly to compression. And no Bovey coal has been discovered, but what has obviously been subjected to mechanical pressure from the superincumbent strata under which it lies. It is, however, principally owing to chemical causes, the wood has probably undergone certain changes, by which it has been softened so as to yield to compression. Trees are often discovered in peat moss in this soft plastic state; they are so changed by chemical agents that they are nearly as soft as a piece of peat. And if such trees were exposed to similar pressure with that to which all Bovey coal has been subjected, they would certainly assume the same elliptical form.

Secondly, All the different parts of the original wood have been detected in surturbrandt. The roots, and stems, and branches, and knots, and bark, and even the leaves, have been found in an organized state. Professor Hollman speaks of many specimens of this description, that have been dug up near Mun-

den. He says, that "the distinct traces of the very leaves were visible." M. De Luc mentions, "that the wood dug out of Messner, resembles, in every respect, that which may be found in a ruined forest, or dug out of peat bogs. I have seen these trees in large heaps, lying on the spot. The stems, branches, and roots, may be distinctly seen."

Thirdly, Not only have all these component parts been found in a *separate* state, but united together in their original form. "The same author observes, that in the same place the trunk of a tree was discovered with a part of the root adhering to it." The branches have also been found adhering to their original trunks. That the small twigs should seldom be seen is not surprising. They are so brittle and tender in comparison with the roots and trunks, that they must have yielded much sooner to compression and disorganization. Hence they are not always, nor even often discovered in peat moss, at least adhering to the parent trunk. Yet Von Troil speaks of specimens of surturbrandt, where the branches were visible. Hollman mentions some which were found at Munden; in which, not only "the longitudinal and transverse fibres are visible, but the annular rings. Some of these trunks are found adhering to the root, and adorned with leaves."

Fourthly, The bark is sometimes discovered adhering to the tree. Sheuhtzer mentions an instance

of this, which was found near Thun in Switzerland. He says, " that some of the trees, dug out of the surturbrandt in that neighbourhood, are still clothed with bark, and here and there adorned with leaves."

Fifthly, The cones and fruit of the trees have been dug out of surturbrandt, in a distinct organized state. Faujas St Fond speaks of specimens of this in " the neighbourhood of Cologne, where the fruit appeared almost untouched."

Sixthly, Sometimes part of the same tree is found in its original state of wood, unchanged; while other parts of it are so highly bituminated, and so much changed, that they can scarcely be distinguished from coal, excepting by their organic structure. " Bomare, mentions an oak tree, found in digging the foundation of the walls of Nanci, fifty feet long and five in diameter. He says, that it was as black as ebony, yet very sound, excepting some knots, which were changed into a kind of fossil coal *."

Seventhly, The traces of aquatic plants are visible in surturbrandt, or the strata that accompany it, as well as in peat. Parkinson observes, that " the clay or schistus, which intervenes between the strata of Bovey coal, is often found to contain vegetable im-

* Some have asserted, that the trees dug out of surturbrandt, like those in peat moss, bear marks of the saw and hatchet, and are cut into pieces of equal length. Beroldinguen takes notice of this. Whether this be the case or not is of small importance.

pressions of reeds and grasses." These are some of the aquatics that enter into the composition of peat moss. If these facts be well ascertained, no doubt can remain of the vegetable origin of Bovey coal, and its alliance, in this respect, to peat moss.

It is true, and ought not to be concealed, that some authors have endeavoured to account for these appearances on another hypothesis. They suppose that there are certain *hidden powers* by which bituminous matter assumes the form of wood. This *mysterious* account of the matter must, at all events, appear questionable. How a mass of bituminous matter, in any situation, should assume the precise form of a vegetable, with which it is supposed to have no connection, and how it should so exactly imitate, not only the roots, and trunks, and branches, but even the leaves and fruits, with all their most delicate and discriminating fibres, appears utterly irreconcileable to analogy. Such a *lusus naturæ* must be deemed incredible. And, if we can account for the origin of surturbrandt on the same principles as peat moss, if it clearly appears to be only another stage of the same process, thére is surely no reason to resort to an hypothesis so mysterious and unaccountable. The chief difference between these two substances seems to be, that the former contains chiefly, if not solely, the remains of ligneous plants; and that these are more completely bituminated and consolidated than the latter. In all other respects, the resemblance is so obvious and entire, that little doubt

can remain of their being formed of similar materials, and by a similar process. To ascribe the one to vegetable, and the other to mineral origin, would therefore appear unreasonable *.

But the alliance between peat moss may be traced a step farther than even in surturbrandt. It may not be improper to pursue this alliance, as it appears in pit coal.

SECTION II.

Pit Coal.

It appears to be the next in the order of bituminous substances. In many respects it is homogeneous with peat and surturbrandt. And there are strong reasons to conclude, that it also is of vege-

* It is not denied that surturbrandt and Bovey coal have been discovered at the depth of some hundred feet. To some this may appear utterly unaccountable, and altogether inconsistent with the idea of their vegetable origin. In reply to this, it may be observed, that it is quite consistent with analogy. The exuviæ of animals have been detected in limestone at a still greater depth. Shells, in a distinct organized form, may be discovered in lime, on the highest mountains, and in the deepest pits. Nay, the exuviæ of vegetable matter, and the trunks and branches of trees, have been found at the depth of thirty, forty, and fifty feet. In the bog of Monela, trees have been found at the depth of forty feet: and, in low Modena, ten feet deeper. Werner observes, that in a vein of Wacken, even *one hundred and fifty fathoms deep*, trees were discovered with the branches and leaves in a petrified state. This is surely more surprising, than to find trees bituminated in Bovey coal, at a much less depth.

table origin. A few facts and circumstances, which lead to this conclusion, may be mentioned; many others must occur to the intelligent reader. And it is believed that no solid objection can be stated against this hypothesis, which may not be obviated on similar principles as those respecting the origin of peat moss.

1. The clay, or schistus, which very generally intervenes between the strata of coal, or forms the roof of it, frequently, if not commonly contains the distinct impressions of reeds and other aquatic plants which contribute to the formation of peat moss. Kirwan takes particular notice of this. He observes that "culmiferous plants, and those of the cryptogamia class, are the most frequently found in Shale." Morand, in his treatise Sur l'art de Charbonier, makes a similar remark. This is no positive proof that these plants have contributed to the formation of coal. The fact amounts to no more than a probability or presumptive evidence, that, if such plants are detected in the strata which accompany coal, it is likely that they have also existed in, and contributed to, the formation of that substance, as well as the clay and schistus which accompany it. But there are much more decisive proofs that coal is of vegetable origin. and that similar vegetables have contributed to its formation, as peat; for

2. The traces of ligneous plants are frequently

detected in the strata of coal itself. These, indeed, are generally converted into pyrites; yet, the original organic structure of the wood may be clearly seen; even the annular rings and ramifications of the tree may be detected. Specimens of this kind may be seen in the cabinets of the curious; and there are very few coal strata utterly destitute of them. The conclusion from this is obvious, that ligneous plants have existed in, and contributed in part, to the formation of coal as well as peat.

Mr Williams*, who had the best means of information, and the most extensive opportunities of examining coal mines, is decidedly of this opinion. He says, that wood "is so obviously the origin of coal, that he could almost trace and point out the particular species which furnished the materials for the varieties of that substance."

3. As wood has been discovered, which was partly converted into peat, so have similar specimens been found in coal. Mr Playfair, in his luminous work†, mentions, "that in the Isle of Skye, pieces of wood have been found, one end of which remains still in its original organic shape, and the other graduates into coal, where there is no vestige of organization." Mr Brand, in his History of the Antiquities of the Town of Newcastle, speaks of similar specimens that have

* In his Mineral Kingdom.

† The Illustration of the Huttonean Theory of the Earth.

been found in Iceland. He says, that " the top of the tree was still wood, while the bottom or root was converted into coal."

Barton in his account of the waters of Loch Neagh, mentions that similar specimens have been discovered in it. " Externally, they resemble wood ; internally, they are altogether bituminous. They are black and glossy, like hardened pitch, and so ponderous, that they sink in water. Some specimens are still wood ; the fibres and original form are still visible to the naked eye ; while other parts of the same tree are completely bituminated. They burn, with a clear white flame like coal."

It may not be improper to take notice of specimens which abound in the vicinity of coal in the parish of Kilsyth. One of these is described in the statistical account of that parish ; it is erected in my garden, and may still be seen.

It was found in a solid stratum of sandstone, standing like the trunk of a tree. It still bears visible and distinct marks of its vegetable origin, though now completely petrified and converted into sandstone. The indentations of the bark, and the marks of the branches, are still obvious.

But the circumstance which claims particular attention is, that it rose from a stratum of coal from below the rock, in which it stood erect. The roots of the tree were so completely bituminated, that they could not be distinguished from the rest of this coal. The cavity too, in which it stood, was not completely

filled with this petrifaction. Round it there was a space of nearly an inch thick, filled with coal. This renders it probable, that part of the bark, as well as the roots, were converted into coal. The whole mass of rock in which it stood is beautifully spangled with charry veins. It appears to contain a congeries of vegetables. Some of these are so distinct and so clearly defined, that the species to which they belong may be discriminated. And no art of the pencil could possibly delineate, with more accuracy, the delicate ramifications of these plants. The stalk of some of them is an inch in diameter; the branches extend in all directions, till they terminate in capillary tubes. The trunk of the tree, already mentioned, was nearly eighteen inches in diameter, in one direction; but being partly compressed, it was not above a foot in diameter in the other. The section of it, like surturbrandt, of course assumes an elliptical appearance. Mr Kirwan takes notice of this, that wood-coal is often found converted into sandstone. He asks, could this have been originally wood? It is replied to this, if ropes and utensils of wood have certainly been petrified, and converted into sandstone, why may not such a tree be subject to the same change?

To form conjectures about the origin of this and similar appearances, which abound here, and in most coal countries, were an idle task: The following is suggested merely for the amusement of the reader. The whole stratum of coal appears to be formed of

vegetable matter, probably from the ruins of some ancient forest. This tree, which stood erect as it grew, probably survived long after the rest fell into ruins. Even after the whole stratum of sand, which forms the rock, ten feet thick, had been accumulated, it must still have stood in its original position, and in that position it seems to have been petrified, during the formation of this rock, while the roots, and other ruined trees below it, were bituminated and converted into coal. Such specimens are very common here; they are generally called *coal stalks*.

The conclusion from this is natural, that if plants of all sizes, from a foot (and upwards) in diameter, to the smallest species, are found partly in the strata that accompany coal, and partly in the coal itself; and if these plants are discovered partly of the original vegetable matter, and partly bituminated, that they have contributed to the formation of coal, as well as peat. And therefore, that coal is either altogether of vegetable origin, or partly mineral and partly vegetable. The former of these conclusions appears more natural than the latter. On the same principles we have been led to conclude, that peat moss is altogether of vegetable origin.

4. The vegetable impressions of aquatic plants, of the same species with those discovered in moss, have been detected, not only in schistus, but on the surface of the coal itself.

Nay, some ligneous plants have been discovered in such an entire state of preservation in that substance, that the species to which they belonged could be ascertained. Chaptal says, that the "bamboo and banana tree, have been detected in the coal of Alais."

5. All the other parts of ligneous plants, as well as the trunks and roots, have been discovered in a state of partial or total bituminization. The bark of trees appears to undergo this change sooner than the trunk; of course, it is for the most part converted into coal, even while the trunk remains entire. Yet in some instances, in coal, as well as in peat moss, the bark is found in its original organization. Mr Brand mentions an instance of this. "While part of the tree was converted into coal, the bark was found adhering to the other part." The leaves are still more liable to change. Yet, as has been mentioned already, in page 50 of my first Essay, the leaves of the alder have been discovered in the schistus which accompanied coal. Mr Hatchett, in his admirable Treatise on Bituminous Substances, mentions similar instances. He observes farther, that "these were not merely vegetable impressions, but the *real substance* of the leaves, *partly bituminated.*" From the accounts which Lwhyd, Butner, Hinknel, Jussieu, and others, give of similar leaves, it would appear, that in some cases, this process has been completed, and the whole leaves have been converted entirely into coal. Volkman, in his Silesia

Subterranea, expressly asserts this. He says, that "a bituminous substance had insinuated itself, and occupied the place they once filled."

If the above facts be correctly stated, (and surely few will question the authorities on which they rest,) we must conclude, that the tenderest and most delicate parts of vegetable matter, may be detected in coal, as well as peat ; nay, more, that these have contributed to the formation of the former as well as the latter. This corroborates the general conclusion, that coal is of vegetable origin.

6. It appears that the gums and resins of ligneous plants are convertible, and have been converted into a bituminous substance like coal. For in Bovey coal, a resino-bituminous matter, which participates of the qualities both of vegetable resin and bitumen, has been discovered *.

Mr Hatchett, by his accurate and ingenious experiments on Bovey coal, and this substance, which accompanies it, has poured in a flood of light on this subject, which formerly remained in obscurity. His analysis of this substance shews, that it contains still a portion of resin, similar to that which exists in the recent vegetable, and a portion of bitumen completely formed.

* In the submarine forests of Lincolnshire, a similar substance has been discovered. So that there are clear evidences, that not only the woody or fibrous parts, but some of the other proximate principles of ligneous plants have been bituminated.

He observes, that " Next to the ligneous part, the resin of trees is that substance which most powerfully resists any change. But, when this change is effected, it is the substance from which bitumen is more *immediately formed*. It not only contains the greatest proportion of the elementary principles of that substance, but is nearly allied to it. The resin that remains in its original state, in the resino-bituminous matter above-mentioned, must be regarded as a part of the proximate principles of the vegetable, which has not yet undergone the necessary change. The bituminous matter, on the contrary, seems to be the product of the same principles, after this change is accomplished."

This appears, therefore, to be the link which unites bituminous to vegetable, or (if bitumen be a mineral,) it is the link which unites the vegetable with the mineral kingdom. It therefore claims more particular attention. That attention has been paid to it, by the justly celebrated Mr Hatchett. His experiments set this point in the clearest light, and establish the affinity which exists between bitumens and the recent vegetables. This will appear from the following facts, which are stated in his own words, as none can more clearly unfold his meaning.

" In the clay adhering to Bovey coal *, a particu-

* A similar substance has been discovered in a stratum of Bovey coal, in the county of Mansfield, near Helbra. Vol. xv. Journ. des Miner.

lar substance is sometimes found. It appears to consist partly of resin, and partly of bitumen. It is of a pale-brownish ochreaceous colour. The fracture of it is imperfectly conchoidal. It seems earthy externally, but internally it is of a vitreous lustre. The fractures of it are irregularly angular, and quite opaque in the edges. It is extremely brittle, and does not apparently become soft, when held in the hand for some time; but it emits a faint resinous odour. Its specific gravity at the temperature of 65° Fahr. is 1=135. Some specimens have dark spots, slightly approaching to the colour and lustre of asphaltum. Small portions of the Bovey coal are commonly interspersed in the larger masses of it.

When placed on a heated iron, it immediately melts, smokes much, and emits a clear bright flame. It yields a fragrant odour, like some of the sweet scented resins. This, at last, becomes slightly tainted with that of asphaltum. The melted mass when cold, is black and very brittle, and breaks with a glossy fracture. All these," he observes, "are the marks of a bituminous substance."

But he fortunately subjected it to an accurate analysis. By this means, he ascertained, on the clearest grounds, the ingredients of which it is composed. and the precise proportion of these ingredients. By that analysis, (the result only of which is now quoted,) he proves, "that it is a substance formerly unknown. That it consists partly of resin, and partly of asphaltum. The proportion of these ingre-

dients he accurately ascertained: one hundred grains contained fifty-five of resin, and forty-one of asphaltum; the residuum was three."

Degner discovered a similar substance in the Dutch peat, by analysis. He calls it a resino-gummous, or pitchy substance. Bertrand found a substance of similar quality in the French peat. He says it may serve the purpose of linseed-oil in painting, and of petroleum in pharmacy.

If we thus discover a vegetable substance, which appears to be in a *progressive state of bituminization*, this becomes a presumptive proof that all bitumens are of vegetable origin; not only these which contain organized vegetable matter, but even those where the organization is destroyed. The resins and gums of trees may have furnished materials for the latter, while the fibrous woody part have contributed to the formation of the former. This proof acquires additional force when we consider farther,

7. That many bituminous substances, as well as this, seem to contain a portion of resin still unchanged. For, like resins, some of them are acted on by alcohol. If so, their alliance to the vegetable kingdom becomes clear. The following experiments, of the same ingenious chemist, illustrate this point.

"The soft brown elastic bitumen of Derbyshire, seemed to undergo no change or solution in alcohol. That liquid, when digested on it, was not tinged. When allowed to evaporate spontaneously, it left no

stain on the glass; of course, it seems to contain none of the vegetable resin in its unchanged state. The process of bituminization, in this substance, appears to be completed.

"But there are other bituminous substances, on which the alcohol operates, and which, therefore, seem still to be only partially changed. Asphaltum appears to be of this description; for alcohol extracts from it a yellow tincture, which, in some cases, seemed to be of a pale olive-colour. When allowed to evaporate spontaneously, a thick brown liquid was deposited, in small drops, on the glass. These drops did not become hard after two months, and they possessed the odour, and every other property of petroleum. The asphalt which was used in this experiment, had lost, in weight, about $1\frac{1}{2}$ grain. Even cannel-coal, exposed in the same manner, to alcohol, communicated to it a pale yellow colour. The same liquid, digested on pit-coal, did not assume any colour. But when allowed to evaporate, by exposure to the air, it left a film on the glass; which, by its odour, was discovered to be petroleum."

Thus, the gradation may be traced distinctly in all its stages. In Bovey coal, and especially in the substance which accompanies it, nature seems only to have performed half her work; one half nearly being still a vegetable resin, and the other a bituminous substance. In asphalt that process is still farther advanced. In cannel and pit-coal it is nearly completed; and in the elastic bitumen of Derbyshire

no traces of vegetable resin can be discovered. It is bitumen fully formed.

SECTION III.

Jet.

THE next in the order of bituminous substances is jet. The alliance between it and peat is a step farther removed; it must therefore be more difficult to trace it clearly. As, in peat moss, the deeper we dig, we generally discover fewer vegetables in an organized state, and its origin becomes less conspicuous, so is it in other bituminous matter. In surturbrandt it is more obvious than in coal; and in coal, still more obvious than in jet. Yet, even in this last substance, where the change is most complete, we may discover distinct traces of its vegetable origin.

A few of these may be mentioned. Geologists who have access to the cabinets of the curious, and opportunities of surveying the subject on an extensive scale, may point out more; and it would greatly tend to elucidate the subject, if they would communicate full information of them to the public.

Jet, in its purest state, as might be expected, is, for the most part, entirely divested of the organic structure of vegetable matter. Yet,

1. As in peat, surturbrandt, and coal, trees have been discovered, partly changed into these substances, and partly in an unchanged state; so the same discoveries have been made in jet. Chaptal mentions an instance of this. His words are, " I preserve, in the Cabinet of Mineralogy of Languedoc, several pieces of wood, whose external part is in the state of jet, while the internal part still remains in the ligneous state; so that the transition from the one to the other may be observed."

2. It is, if possible, a still clearer evidence of the vegetable origin of jet, that specimens have been discovered, in which one end of the same tree was converted wholly into jet, while the other remained in its original state. Fourcroy mentions instances of this.

3. In other specimens, the tree, though wholly converted into jet, still retains its original organic form, and fibrous appearance. Parkinson mentions a specimen of this kind. And Chaptal says, that "in the environs of Montpelier, several cart-loads of trees have been dug up, whose form was perfectly preserved, though entirely converted into jet."

4. In some specimens, the organic structure of the plant is so perfect, that the species to which it belongs may be ascertained. " In the neighbourhood of Vachery, in Gevaudan, (the same author observes,) a jet is found, in which the texture of the *walnut-tree* is very discernible. The texture of the beech is seen in the jet of Bosrup in Scania."

5. Utensils of wood have been discovered converted into jet. "I have," says Chaptal, "found a wooden *pail* converted into this substance." He likewise mentions a wooden shovel which had undergone the same change.

Thus, the alliance between peat, surturbrandt, coal, and jet, may be traced. In the first of these substances, the trunks, roots, branches, bark, leaves, and seeds, of ligneous plants, may be all distinctly seen. Nay, every species of aquatic plants, of which it is partly composed, may be discovered in a distinct entire organic form, where the smallest seeds and capillary tubes may be traced. In the second, only ligneous plants have been detected; yet all the parts of these, in a partial or entire state of organazition, may be detected. In the third, the same discoveries have been made. Nay, even in jet itself, there are specimens which exhibit as distinct marks of organization as in coal. In neither of the two last-mentioned have aquatic plants been often detected. But in the schistus and solid rock which accompany both, they may be distinctly traced. Though, therefore, the vegetable structure becomes fainter in surturbrandt than in peat; in coal, than in surturbrandt; and in jet, faintest of all; yet, the alliance between all of these substances, may still be distinctly seen, from one extreme to the other *. And the vegetable origin of all of them appears much more obvious, when the alliance that

* Guitard accordingly considered peat moss as an imperfect jet.

each bears to the other is thus traced. The gradation, in this case, is quite of a piece with the analogy of nature in other cases. And if we are led to conclude, according to Dr Hutton, that a solid rock of limestone, which contains one single shell, is homogeneous, and of the same origin with a piece of marl, where every shell may be discovered in an organized state, the conclusion is as obvious in the case of all the above bituminous substances. They are all links of the same chain. In other words, they all form gradations of the same process. In peat, that process is only begun; in surturbrandt, it is advanced a step farther; in coal, it is nearly complete; and, in jet, it is fully accomplished.

This will appear in a still clearer point of view, if we can shew that there is an obvious alliance between the two extremes, *i. e.* between the softest and most porous peat, on the one hand, and the most solid compact coal, on the other.

This is reserved as the subject of another Section.

SECTION IV.

Of the Alliance between the softest Peat and the hardest Coal.

If that alliance can be more clearly established, it may tend to illustrate the natural history and ori-

gin of both. In external appearance, few substances are more dissimilar. The difference between them is obvious to the naked eye. The alliance that subsists between the one and the other, is by no means obvious at first sight. Nor is it to be expected, that it can be so clearly traced between these extremes, as between any of the intermediate stages of the process. To awaken our curiosity, and excite our admiration, the GREAT CREATOR of all has thrown a veil over the commencement and consummation of every process in nature. Some of the intermediate steps may be traced. But these extremes are generally hid in obscurity. It is only by patiently tracing every intermediate link, that we can see the connection between the beginning and the end of these processes. This has been attempted in the foregoing Sections; and, from what has been there stated, we may be better prepared to discover how these extremes are linked together.

The following facts, it is hoped, may exhibit this connection in a clear and decisive point of view.

1. It is certain, that the softest and most porous peat, by mechanical pressure alone, may be converted into hard. Poiret, (as has been stated already, in the second Essay), takes notice of this. He says, "that fibrous moss, though light and loose, may, by this means, be hardened to such a pitch, as to receive a polish like wood." If any person doubt of this, he can easily satisfy himself by a simple experiment.

The alliance between the softest and hardest peat, has already been stated. The difference that subsists between them may likewise be accounted for in this way. The former may be converted into the latter by pressure alone.

2. It is equally certain, that moss, however soft and pulpy when dug, if grinded and compressed in the manner in which the Dutch form their peat *, acquires the density of, and becomes specifically heavier than coal. " Mr Lind has ascertained this by a simple experiment. The following was the result: Taking water as the standard, as 1000, coal was 1287; whereas peat, formed and compressed as above stated, was 1303."

The reader may also satisfy himself on this point by the following experiment: Take a quantity of black pulpy moss, from the bottom of the pit, squeeze out all the water from it, and then grind it into powder, and put it into a press. When subjected to compression for a time, he will find the peat, thus formed, specifically heavier than some coal.

3. Some peat when dug, even *without* this mechanical *pressure*, becomes so hard, so heavy, and so glossy in the fracture, that it is with difficulty that it can be distinguished from some of the softer coals. On the contrary, Mr Williams says, that he has seen

* The manner in which peat is baked in Holland, will be described in a subsequent Essay on Fuel.

coal so soft, that it was equally difficult to distinguish it from the hard black glossy peat.

Dr Rutty mentions, " that he had in his possession one dug near Newbury in Berkshire, of this description. It is very compact. It is so hard, that it breaks glossy like coal, and so heavy, that it sinks in water."

Such specimens of peat are not very common. The late Professor Robison, so justly celebrated as a natural philosopher, mentions one. " It is to be found at Canisbay, in the northern extremity of Scotland, near John-o'-Groat's house. Though almost an impalpable pulp, when first dug, yet, when dried, it is so fine in its texture, as to break with a sort of polish like *a jasper*. Its smell, in burning, is not very distinguishable from cannel-coal. The smell of the best Dutch peat, taken up from the bottom of salt water, resembles this very much."

Peat of a similar description may be sometimes discovered along the sea-shores, especially where it has been laid over with a considerable stratum of sand, and thereby compressed. In the western islands, and along the coasts of Cumberland and Lancashire, as well as the north-east shores of Scotland, such specimens may be seen. They approach nearly to coal in colour, consistency, and every other quality. Specimens have been sent to me from various quarters; and it would be esteemed a singular favour, if any person, into whose hands these Essays may come, would furnish me with more.

In cutting the great canal through the parish of Cadder, the workmen had occasion to pass through a moss. The sandy subsoil, which now forms the banks, is there laid over part of that moss, to the depth of ten or fifteen feet in some places. By compression, this stratum of moss is already condensed. In the course of ages, it may, by this means, be converted into a substance equal in consistency to coal, and not distinguishable from it in chemical qualities.

4. There are the strongest reasons for supposing, that all coal has been, at one period of its formation, in a soft pulpy state, like the above species of peat, when it is newly dug. The smooth glossy appearance of the surface and bottom of that substance, its laminated texture, the distinct and very delicate impressions of the finest fibres of vegetables, which appear on it, all lead to this conclusion. For if coal had always been as hard as when dug, no delineation of any vegetable could have appeared; no indentations or impressions could have been traced on it. It could not have assumed the glossy appearance, which is always a distinguishing feature of that substance.

Coal may sometimes be seen in this state, at least a liquid bituminous matter sometimes exudes from the seams of coal. It appears in the form of drops, and is called, by the workmen, tears of the mine. The probability is strong, that the whole mass of coal was, at one period, in a similar state of fluidity, though now consolidated by compression.

If it has ever existed in this soft pulpy state, it is obvious, that compression alone is necessary to give it that solid, compact, glossy appearance.

And it may be added,

5. That coal, wherever it has been discovered, has certainly been exposed to a degree of mechanical pressure, far beyond that which has ever been applied to peat by art. Of this, it would be superfluous to offer any proof. And if the best peat were subjected to the same degree of compression, it is obvious, that it would become equally compact, and equally heavy, bulk for bulk, and equally inflammable as coal; and in no respect distinguishable from that substance, in colour, consistency, or chemical qualities.

Professor Robison observes, accordingly, " that peat mosses form regular strata. These lie, indeed, on the surface of the earth ; but if any operation of nature should cover them with a deep load of other matter, the moss would be compressed and rendered very solid. Remaining, for ages, in that situation, it might ripen into a substance very like pit-coal.

Sir James Hall, whose experiments on this subject have so justly excited attention, observes in a letter to me, " I have not made any experiments on peat with heat and compression; but I have little doubt that coal would be so produced, as well as from every animal and vegetable substance. I have always looked upon the peat of the old world as one of the principal sources of our coal."

The chief difference that subsists between the hardest and most compact peat and coal, seems to be, that the former contains more water, and more acid, than the latter. Bulk for bulk, they often contain nearly an equal proportion of bitumen. Compression alone might remove this difference. It is not insinuated, that this is the case with every species of peat and coal; but that the former may be converted, by means of compression, combined with certain chemical agents, into the latter, appears certain *.

Most probably it is in this way that all coal strata and surturbrandt have been originally formed. A ruined forest, or a mass of vegetable matter, such as is contained in moss, may have been overwhelmed by a current of *lava*, or overrun with a bed of *sand*, or argillaceous or *calcareous* matter, or buried in the caverns of the deep by the *flood*; in all of these cases, this matter must have been subjected to such a degree of compression, as is sufficient to consolidate it into a substance like coal or surturbrandt. And, by this means, we can account for these substances being found under strata of basaltes, freestone, schistus, limestone, or marl.

It were an easy task to point out situations where this process is actually going on. For instance, it is not an uncommon event for a forest, or morass, to

* A number of experiments on this subject shall be submitted to the public, in a subsequent Essay, on Peat Moss as a Fuel.

be overflown with lava. On the sea shores, too, we often see a stratum of moss, or a forest, overwhelmed in sea sand. And, in innumerable instances, clay or argillaceous, and marl, or calcareous matter, is deposited by alluvion on the surface of a morass.

M. De Luc, in his letter to me, observes the following: "The history of peat bogs along the sea coasts, is a subject in geology which has much engaged my attention; especially along the shores of the Baltic and the North sea.

"Along the Elbe, and elsewhere, submarine peat may be frequently seen. It has glided under the water, where there is a declivity from the continental soil, on which are large peat moors. Nay, it appears, that though covered with the muddy sediment of the river, or the sea sand, it does not cease to move forward under them.

"Along the coast of Lincoln and Devonshires, and Somerset, the same phenomenon may be observed. These I conceive to be a flowing of peat from the land under the water of the sea. I have seen, in Torbay, opposite to the meadows of Tor-abbey, some branches of trees at low water in the mud. I was told that whole trees are sometimes discovered; and I found, myself, lumps of peat peeping out of the mud."

It may be added, that such morasses often contain the trunks of trees, so soft and pulpy, though partly bituminated, that, when they are thus subjected to mechanical pressure, they must assume all the ap-

pearance of surturbrandt. The annular rings must assume the form of ellipses. The knots must be so compressed into the yielding body of the tree, as to exhibit all the twisted and unnatural appearance which surturbrandt assumes. Other morasses, on the contrary, contain a vast proportion of soft and pulpy, and highly bituminated peat. These, by the above means, must assume the glossy and solid appearance of coal. The vegetable matter on the surface, which existed in an organized state, when it was subjected to such an irruption, must, by incorporating with the sand, or argillaceous matter, communicate all the appearances, and *leave* all the vegetable impressions on the surface and roof of this coal, which are so common in the strata that accompany that substance.

6. The external appearance of coal shews its alliance to peat. In colour and consistency, the resemblance is often clear.

Peat is often of a fibrous texture, and brown colour. Brongniart, accordingly, in his classification of that substance, ranks this in the first order. Brochant, in his classification of coal, places brawnkhole, or la houille brun, also, in the first order of that substance. It, too, is fibrous, as well as the peat above-named, and bears distinct marks of the organic structure of vegetable matter.

Peat is sometimes found of a foliated texture, like thin leaves of paper, firmly compacted together. Brongniart calls this, tourbe papyracée, and reck-

ons it in the second order of that substance. The schiffer-khole of Werner corresponds to this. It assumes the same laminated appearance,

Peat is sometimes of a soft pulpy consistence, totally divested of vegetable organization. Brongniart calls this tourbe limoneuse. The moor-khole of Werner bears a near resemblance to this. Brochant calls it la huille limoneuse.

Peat is seldom, though sometimes, discovered of a resinous lustre, and very compact. Brongniart accordingly calls it piciform. The peck-khole of Werner is very much of the same appearance; and Brochant gives it the same name, la huille piciform. They are both of the same colour, as black as jet.

In peat, the bark of the birch tree may be seen in all its original lustre. The whole moss seems to be spangled with it. Some coal assumes precisely the same appearance. The glantz-khole of Werner, or, as it is called by Brochant, la houille eclatante, is of this description.

Peat is very frequently mixed with argillaceous matter. It is, of course, heavy, and yields much more ashes than the other species. The laminated coal of Brochant, or, la houille schisteuse, corresponds precisely in all these respects.

Peat is often found mixed with pyrites. Brongniart calls it vitriolic. This species is frequently covered with a stratum of chalk, sand, or clay. Thin strata of these substances are sometimes discovered in these mosses; and they have a subsoil of marl.

The blatter-khole of Werner corresponds to this. It likewise contains pyrites, and is often discovered under a roof of limestone, or in its immediate vicinity.

Peat is sometimes so impregnated with a bituminous oil, that it will burn like a candle, with a clear white flame. The Ince peat in Lancashire, and the greasy clods of Aberdeenshire, are of this description. And the hennel-khole, or la houille de Kilkenny, of Brochant, bears a strong resemblance to this species of peat.

On the contrary, peat is frequently found, especially on the surface, and still more in warm climates, so entirely divested of bituminous oil, that it is scarcely inflammable, and cannot be formed into fuel. It is ROTTEN, (as it is called) and crumbles down. The blind-coal bears a near resemblance to this. Whether the grob-khole of Brochant be of this description, he does not say. He calls it, however, la houille grossière.

And Mr. Williams observes, that such coal, like this rotten peat, exhibits no regular perfect form, or grain, in working. It breaks into mis-shapen globes, like peat-clods broken in water.

To assert that each of these species of peat furnished the materials for the distinct species of coal which corresponds with it, might appear presumptuous. It will not, however, be deemed so, to assert, that this marked resemblance clearly evinces the alliance that subsists between these two substances,

More especially, when it is added,

7. That this resemblance may not only be traced in the external appearance, but in the *chemical qualities* which both discover, on analysis. As this is the severest, so it is the surest test which can be applied. If two substances, however dissimilar in external appearance, yield by analysis the same result, in the same order and proportion, the probability is, that they are homogeneous, and of the same origin.

It is not asserted, that any peat yields precisely the same elementary principles as coal. Nor is it insinuated, that any one species contains the same proportion of these. Even coal itself does not always yield the very same elementary principles; some species contain extraneous matter that cannot be detected in others; and all the species yield different proportions of those elements which enter into the composition of coal.

It is, however, a presumptive proof of the vegetable origin of peat, surturbrandt, and coal, that all of them, by distillation, afford nearly the same elementary principles with vegetable matter, viz. air, water, an acid, an oil, salt, and earth. And though the proportion of these ingredients may differ in these substances, and even in different species of each of them, yet the elements of which they are composed, are not only nearly the same, but are evolved in the same order.

The following tables may probably illustrate this

point. Some of the analyses of peat were made before pneumatic chemistry was much cultivated. On this account they are less to be depended on. Le Sage distilled 18 oz. of French peat. Mr Lind analysed 5 oz. of moss, found near Edinburgh. The following is the result, as stated by these authors.—

I.

18 oz. of French Peat.

	oz.
1 of water	2
2 oily saponaceous matter	$1\frac{1}{2}$
3 volatile alkali	$4\frac{1}{2}$
4 concrete	$\frac{1}{16}$
5 residuum, destitute of salt	$9\frac{1}{2}$

II.

5 oz. Scotch Moss.

	oz.	dr.
1 of water	$1\frac{1}{2}$	
2 oil, yellow at first, but it became darker in colour	2	
3 acid, yellow liquor		$2\frac{1}{2}$
4 empyreumatic liquor		6

These analyses are very imperfect in one respect. No account is made of the gaseous matter that escapes during distillation. The hydrogen, carburetted hydrogen, and carbonic acid, which are evolved during that process, are entirely left out of the account. Of course, the sum total of the ingredients, in both cases, comes short in weight of the moss distilled.

The author has made several attempts to analyse peat, according to the modern method. The result he declines to state, for the following reasons.—That he cannot pledge himself for the accuracy of these experiments, and that different species of that substance, yield vastly different proportions of the

same elementary principles. Some yield a great, and others a small proportion of oleaginous and gaseous matter.

All the various species he has examined, however, yield water, an acid, an oil, charcoal, and a considerable proportion of the following gases: hydrogen, carburetted hydrogen, and carbonic acid. From the following accurate analysis of Bovey coal, &c. by Mr Hatchett, it will appear, that these substances are homogeneous to peat moss.

Analysis of Bovey Coal, the Bituminous Substance that accompanies it, and of Brown Coal. By Mr Hatchett.

1. Bovey Coal.		2. Bituminous Substance which accompanies it.		3. Brown Coal.	
100 Grains yielded	Gr.	100 Grains yielded	Gr.	100 Parts yielded	Pts.
1. of water that became acid and turbid, by a mixture of bitumen	30	1. water, slightly acid	3	1. water, slightly acid	30
2. thick brown oily bitumen	10½	2. thick brown oily bitumen	45	2. bitumen	10.5
3. charcoal	45	3. light spongy coal	23	3. charcoal	45
4. mixed gases: hydrogen, carb. hydrog., carb. acid.	14½	4. mixed gases: hydrogen, carb. hydrog., carb. acid.	29	4. carb. acid and carb. hydrogen	14.5
Total	100	Total	100	Total	100

From the above table it appears, that each of these subtances yields, on the strictest analysis, the same elementary principles, and in the same order. It farther appears, that Bovey coal and brown coal yield precisely the same proportion of these elementary principles. The bituminous substance which accompanies Bovey coal differs from the other two, in the following respects: It contains ten times less water, but nearly nine times more bitumen, and double the quantity of gaseous matter. Yet who can doubt that all these substances are homogeneous? And if the first be decidedly of vegetable origin, who can doubt that the last may be traced to the same source? especially since peat moss, which is obviously, and almost altogether, composed of vegetable matter; and even recent vegetables themselves, by the same process, yield the same elementary principles, in the same order, though in different proportions. This difference can be easily accounted for, on the hypothesis that they are all homogeneous; whereas, the affinity that exists between all of them appears to be irreconcilable with the idea, that one only, viz. peat moss, is of vegetable, and all the others of mineral origin. To suppose that a mineral substance should so precisely correspond in chemical qualities, and contain exactly the same elementary principles, in the same order and proportion, with one that is composed of vegetable matter, is, at least, apparently inconsistent with analogy.

To some, however, this branch of the subject may appear obscure, and the reasoning founded on it questionable. It may, therefore, be proper to state a fact, which furnishes a more palpable proof of the alliance between peat, surturbrandt, and coal.

8. These substances are sometimes found in alternate layers. And the surturbrandt, which has been shewn to be so nearly allied to peat, and so obviously of vegetable origin, has sometimes been found immediately above, and sometimes immediately *below* the coal.

Professor Hollman describes the immense strata of surturbrandt that are discovered near Munden. In one place, he says, there is a layer of this substance twenty feet thick; below it a foot of stone. Piercing through this, he adds, that another stratum was discovered, thirty feet deep. So that there must be upwards of fifty feet of surturbrandt in all, as the borers had not reached the bottom. Between these strata of fossile wood, he observes that, in some places, was discovered a vein of *hard black bitumen*, almost of the *consistency* and *colour* of jet. This stratum was sometimes a foot or more in thickness.

Mr Kirwan takes notice of a similar stratification. He says, that "*wood coal* and *bituminous stone coal*, frequently accompany each other. Sometimes, as at Meisen, the stone coal is uppermost, and the wood coal *under it*. At other times, the wood coal is discovered above the stone coal, as at Toplitz in Bohemia."

Beroldingen observes, " that at Meissner, one of the mountains of Hesse, coal and surturbrandt alternate. The latter, in this case, lies *below* the former. Yet it still retains the fibrous form and annular rings of the original trees. The branches of these may still be distinguished. The trunks are entire. Both the coal and surturbrandt lie under a roof of *basalt.*"

He concludes from this, that they are the remains of an ancient forest. And he supposes that this forest has been overwhelmed by an eruption of a volcano. Whatever may have been the revolution, by which such an immense quantity of wood has been buried so deep in the earth, it is obvious, that it has furnished the materials, both for the surturbrandt and coal. The conclusion, therefore, is obvious, that they are both of the same origin.

M. De Luc has repeatedly visited that district of Europe. On corresponding with him on the subject, he kindly communicated the following fact, to which he called my particular attention. His words are,

" There is a circumstance with respect to those peat mosses, which I don't think I have mentioned to you. The whole of that country abounds with blocks of granite, and they are often found in the mosses. Some of them are not entirely covered with peat, others are discovered in digging it. This, among many other circumstances, shews the error of those, who have supposed that these blocks have been detached from the mountains, and propelled

along the surface, by running waters. For in these spots there never has been a stream. They have been only pools, at the origin of our continents. But this stands connected with a very interesting geological fact, with respect to peat. I have seen, in *many cases*, pure *fossile peat*, in the same situation as coal. For instance, Mount Messner, in the country of Hessen Cassel, contains thirty feet thick of that pure fossile peat, resting on limestone strata, and covered with basaltes. This stratum being worked for fuel, I had an opportunity of examining it in its whole thickness. At the top, under the roof, where the peat is only separated from the basalt by some more tender argillaceous strata, it is absolutely *unaltered*; a proof that the incumbent strata are not the effect of fusion. At the bottom, among stems, and branches, and roots, and trees, such as are found in deep peat mosses, I saw, in many places, that the miners had been obliged to bend their course, on account of *blocks of granite*, which they met in their way. This phenomenon, united with the trees, and *blocks of granite* found in the bottom of actual *peat mosses*, is a great monument in the history of the earth, and elucidates my opinion as to the origin of these blocks, and also of coal."

Barrow, in his travels, mentions a still more remarkable stratification at the Cape of Good Hope. "Under the direction of Lord Macartney, an attempt was made to discover coal, on account of the scarcity of other fuel. A small seam was discovered, two

feet thick. In some parts of it ligneous blocks were discovered. These bore evident marks of the bark, and knots, and grain of wood. Pieces of pyrites were detected, imbedded in the middle of these blocks. Other parts of the stratum consisted of *laminated coal*, of the *nature of turf*, and pieces were discovered, which differed nothing from Bovey coal." Here, peat, coal, and surturbrandt, were all blended together in one mass.

These facts speak for themselves. They speak a language explicit and intelligible, so as to leave little doubt, of the alliance between all these three, and as little doubt of their vegetable origin.

9. The strata which generally accompany coal, and the extraneous matter found in it, shew the alliance to peat.

1. *Calcareous* matter frequently accompanies coal strata.

Shells are often discovered in the schistus which covers coal. The very species to which they belong, may be known. At Valenciennes, fluviatile shells are found imbedded in schistus.

Similar shells are frequently discovered in the clay which covers moss.

Marine shells are found in the schistus which accompanies the coal, at Meilen on the Alps. Brongniart mentions, that similar shells are found in the mosses in the vicinity of Soisons. The same is the

case in many of those which lie along the sea-shores of Britain, and the Continent of Europe.

Marl sometimes forms the roof of coal. At Angen and Hardingen, in the Boulognnois, this is the case.

Marl also is often found on the surface of moss. Instances of this have been already mentioned.

Limestone frequently forms the roof, or pavement, of coal. At Gilmerton near Edinburgh, at Blackburn, and Carlops, such stratification may be seen.

The mosses along the banks of the Somme are covered with a stratum of tufa and calcareous earth.

Calcareous rocks often intervene between the seams of coal. Brongniart observes, that strata of shells are frequently found in moss. They form distinct and alternate layers with it.

Calcareous matter is sometimes found blended through the whole stratum of coal. It is so intermixed, that it cannot be distinguished but by the colour which it communicates to the seam. But when the coal is burnt, it affords lime, and, even before it is burnt, it effervesces with acids. This is the case with the coal of Alais. Many of those mosses which lie along the sea-shore are equally mixed with calcareous sand.

2. *Argillaceous* matter frequently accompanies coal strata. The roof and pavement commonly consists of schistus, or indurated clay.

Sometimes *white argil*, or potter's clay, is found immediately above or below a seam of coal. Speci-

mens of this have been discovered at Noyant, in the Bourbonnois, and Colebrook-dale in England. The same substance often accompanies surturbrandt. Mosses are frequently found with a similar subsoil. Many in this neighbourhood are of this description.

The schistus which accompanies coal is frequently filled with *vegetable impressions*. Sometimes a congeries of *leaves* is found in it. At St Hippolite and La Laye in Alsace, and Gabelier in the Bourbonnois, this is the case. In nine cases out of ten clay forms the subsoil of moss. Sometimes it is covered with a stratum of that substance. And vegetable impressions of the same species, and leaves of the same kind, are frequently found in that clay, as in that which accompanies coal.

3. *Siliceous* matter, and freestone, for the most part forms the roof and pavement of coal. This is frequently mixed with sulphur and iron. In like manner, a deep bed of sand frequently covers or forms the subsoil of moss. This sand is, in every respect, similar to sandstone, if it were cemented together.

Small gravel, formed into hard stone, is sometimes found between coal strata, as in Shaffenberg in Westphalia. Peat has also been discovered in alternate strata with gravel. Mr Shirreff, who surveyed Zetland, in summer 1808, for the Board of Agriculture, very politely sent notice to me of an instance of this. " I noticed" says he, " peat, three feet deep ; under it there was a stratum of gravel nine

inches deep; below this a foot of moss; and, under all, a similar gravel."

Quartzoze stone is also found to accompany coal, as at Gresthorn, in the Trois Eveques. In the parish of Cumbernauld there is a peat moss with a similar subsoil. Along the shores of Fannyside loch, this stratum is laid open, and the quartzoze sand may be seen, both loose and in the solid form of rock.

4. *Pyrites* very frequently incorporates with or accompanies coal. Innumerable instances of this might be mentioned. Many mosses also abound with it.

The chief difference that subsists between the strata that accompany coal and peat, is this, that, in the former, these strata are consolidated, in the latter, they are generally loose. The calcareous and siliceous matter that accompanies coal, is formed into marl, limestone, or rock. That which accompanies peat, is in a loose friable state, seldom consolidated. The clay too is indurated which accompanies coal. That which is found under, or above moss, is generally less solid. But this difference may be easily accounted for. The calcareous and siliceous matter in moss, needs only a cement to convert it into the same consistency as that which accompanies coal; and such a cementitious matter is often discovered. A petrifying spring, when allowed to permeate a quantity of loose shells, converts the whole into marl, or solid rock. Even sand may be cemented together, in a similar manner, into a solid rock.

Saussure mentions, that " in the neighbourhood of Messina, where gritstones are quarried near the sea-shore, " the cavities are soon filled up with sea sand, which, in a few years, becomes solid rock." Bowles, in his History of Spain, says, " that the sea, in the neighbourhood of Cadiz, possesses a similar power. The fragments of brick, mortar, &c. thrown on the shore, are cemented by the sand and shells into a uniform mass of stone, after a certain period of time."

If a bed of marl, or sand, or gravel, under or above any moss, were overrun by such springs, or impregnated with such matter, it would thus be converted into a solid rock of marl, freestone, or breccia. And that the solid strata which accompany coal have been consolidated by similar means, there can be little doubt.

By this means, too, we may account for the formation of freestone rock, above or below coal, and how moss may be converted into strata scarcely distinguishable from it. It is true, that coal strata are seldom found single. Below one many more are for the most part found. But the same is often the case with moss. In the bog of Monela, and at low Modena, and all along the shores of the Baltic, and the coast of Holland, moss is found lying layer upon layer, to the depth of 40, 50, or 70 feet, with intervening strata of earth, sand, clay, or calcareous matter. The same is the case in the carses of Gow-

rie and Falkirk *, and probably along all the shores of Great Britain. If such a cementitious matter were to incorporate with these strata of sand, or calcareous matter, as is found along the sea-shore at Cadiz, and elsewhere, it is obvious, that such mosses would exhibit all the appearance of surturbrandt and coal, in alternate layers with lime and free-

* The following stratification was laid open in the carse of Falkirk, by Mr Walker, on the estate of Lord Dundas, near Dorator.

"The surface is moss, covered with rushes, and coarse aquatic plants. This moss is about 5 feet thick. Below this, lies a stratum of clay, mixed with calcareous sand. This is four, five, and, in some places, seven feet thick. Below this is another stratum of moss, very black and solid, and fit for fuel. Below this lies a stratum of sand, the thickness of which is not known. When a rake-shaft was pushed into this sand, the water rushed up with impetuosity."

In the carse of Gowrie, and along the banks of the Earn, a similar stratification may be seen. At the depth of from 18 to 30 feet a stratum of moss is discovered, from two to four feet thick, composed of wood and aquatic plants. The peat is very compact. Immediately above it a stratum of sand is also found, and abundant springs issue from it. The water of these is excellent. But if they dig through this low moss, the water then becomes so bitter and nauseous, that it is unfit for the use of man or beast.

In the vicinity of Rotterdam, a similar stratification has been laid open. It is mentioned by M. De Luc.

1. A stratum of moss, mixed with clay	20 feet deep.
2. Below this a light white clay	14
3. Below this, moss mixed with clay	8
4. Consisted of a compact clay	14
5. A white tenacious clay	4
	70

Compare the above with the stratification of the bog of Mencla, and the marsh of Low Modena, as described in the 2d Essay, pages 227 and 229.

stone rock. The argillaceous matter, by compression alone, may be converted into schistus.

Such mosses may be considered as coal in a nascent state. And in the course of ages they may undergo such changes, and be exposed to such a degree of compression, that they will scarcely differ from that substance, in colour, consistency, or chemical qualities.

10. There are many other circumstances which shew the alliance between peat and coal. Suffice it only to name a few of these.

Both coal and peat are of a laminated texture. In the latter, these laminæ may be seen with the naked eye. In the former, they are frequently as conspicuous. In both, there are a few exceptions to this. Some peat and some coal are utterly destitute of this external appearance.

The more moisture that accompanies both, they are the more inflammable.

The lowest strata in both are generally most inflammable, and most impregnated with bitumen. To this there are very few exceptions in either. The surface of most mosses is generally possessed of little bituminous matter, and, of course, less inflammable than the substrata. The outburst of all coal is possessed of less inflammability than the rest of the seam.

Both are supposed by some to be renovated when dug. Of the renovation of peat moss little doubt can be entertained. That of coal seems probable.

Mr Gennete says, "he was an eye-witness of the fact." He describes the manner in which coal is renovated in the Liege mines. "A bitumen, impregnated with carbon, transudes through the veins, which forms coal. In forty years the wastes are filled up with it." He says, that he saw this new-formed coal.

Moisture seems to be requisite to the renovation of both. Hence the common saying, that water is the mother of coal. The same may be said of peat.

Both spontaneously take fire. Instances in which this has been the case in peat mosses have already been mentioned. To enumerate those cases in which coal strata have spontaneously kindled at St Etienne, in Forez, at Crainsac, in Rouergue, at Roquieremade near Beziers, and in Britain, were an easy task.

Both are stripped of their inflammability and tenacity, and other distinguishing qualities, when long exposed to the air, and the alternations of heat and cold, moisture and drought. They both crumble down into powder, and cease to be inflammable.

Some peats are highly bituminated, and emit much flame; others burn with difficulty, and yield little or no flame at all. There are also what is called blind coal, corresponding to the last, and cannel-coal, yielding flame like the first.

As all the distinct species of peat graduate into each other by such insensible shades, that it is difficult, if not impossible, to draw a distinct line of se-

paration between them, so the same is the case with all the varieties of coal.

These, and many other circumstances, led Mr Williams to make the following remark: " I have seen strata of coal that bore all the imaginable marks of being composed of wood. The colour, the quality, the stratification, the manner of burning, the ashes, and every thing else, looked like peat."

M. De Luc, in one of his letters to me, makes a similar remark: " Our coals have had for their origin, peat moss, formed on islands of the ancient ocean. These having subsided, have been covered with strata under the sea*. But there must have intervened some cause of mineralization, to change peat into coal. And where that cause has been awanting, peat remains unchanged. The fossile peat of the mountains of Hesse is of this description. It has all the characters of seams of coal. Sandstone strata cover it. At Messner it is covered with basalt. I have been in the quarries whence it is dug.

* In his letters to the Queen, he specifies an island in the Baltic. " It is called Borholn, and is surrounded with hills of sea sand, but the centre of it consists of a vast peat moss. Under the whole lies a quantity of fir-trees. If such an island were entirely overwhelmed by the sea, as it is in part, we may thus trace the origin of coal strata. Here, the leaves on the surface, tossed about with the waters, and deposited with the slime with which they were impregnated, would form a stratum of leafy schistus, with vegetable impressions on the surface of the peat. Various strata of sand would thus be accumulated; the moss would thereby be compressed and consolidated. Shut up in this laboratory, it must there undergo great changes.

The upper part is a mere pulverized peat. The under part is surturbrandt.

The author is fully aware, that formidable objections have been urged against the vegetable origin of coal, by geologists of the first rank. To obviate these is not his object. It is a task far above his talents. He leaves it, therefore, to those more versant in the subject, and is satisfied with the more humble office of stating plain facts.

Kirwan has summed up these objections. In his excellent treatise on geology they may be seen in their collected force. Arduino and Guisauno may also be consulted.

One objection, however, is so obvious, and so palpable, that he cannot pass it over in silence. It must occur to the most superficial reader:

"If peat, surturbrandt, and coal, be of vegetable origin, why may we not imitate these substances by art? If this could be done, there would remain less doubt as to their origin; whereas, all the evidence hitherto adduced rests on analytical reasoning."

A few remarks on this objection may not be deemed superfluous.

11. Artificial fuel, analogous to peat moss, has been used in many different quarters. In Westphalia, Drenthea, and Velavia, Degner says, "that the inhabitants mix heath with earth, and burn it in the form of peats. In Friezland, Malabar, the Orkneys, and in Egypt, straw, reeds, leaves of trees, and other vegetables, are mixed with the dung of

animals; and when dried, they are used as a fuel. The refuse of tanner's bark, mixed with dung," he says, "is also used. In form, colour, consistency, and weight," he adds, "this mixture can scarcely be distinguished from real peat. It is equal, in quality, to the middle kind of moss. And the ashes of it are precisely similar to those of turf." It is said that the Arabs use a compost, somewhat similar: old thatch, and the refuse of grapes, mixed with camel's dung, and dried in the sun, catches fire sooner, and yields a more intense heat than Dutch peat, or even coal.

All these are compositions somewhat analogous to peat. None of them, however, can be considered as a correct imitation of that substance. To form this, it is absolutely necessary that every ingredient, and in the same proportion, which is extracted from any species of peat which is meant to be imitated, ought to be combined. In this way it is certain that any species may be so exactly imitated, that in colour, consistency, and chemical qualities, the artificial cannot be distinguished from the real peat. To prove this, it is only necessary to try the following experiment. Take the same proportion of the ingredients of which any moss is composed, and knead them together into a paste, and dry them in the sun, and compare them with any piece of real peat, formed of the same ingredients. This experiment may be considered fair, excepting in one respect. During the distillation, or combustion, of any kind of moss, a

great proportion of the bituminous matter escapes in the form of gas, or carburetted hydrogen. This cannot be so easily collected, nor, though collected, can it be so easily compounded with the artificial peat. In the formation of it, therefore, there must be an allowance made, and as much more bituminous oil must be added to the mass, as will make up for, or counterbalance that which escaped from the real peat as an aeriform fluid.

Specimens of this artificial moss may be thus made and exhibited at any time. And when these are compressed like real peat, they assume the same concrete appearance. When black pulpy moss is thus imitated and compressed, it acquires a colour, density, and weight, little inferior to coal.

Hence coal itself has been imitated. Venel observes, "that if the same earths, of which it is composed, be collected and baked together, with a quantity of petroleum, this artificial coal will assume the appearance and possess similar qualities with that substance." Brochant observes, "that the Persians form an artificial coal in a similar manner. As naphtha abounds among them, they mix it with earth, and use it as a fuel." But the experiments of Sir James Hall, that ingenious and indefatigable philosopher, throw much light on this subject. They are detailed in the Transactions of the Royal Society, Edinburgh, 1805. "By a very moderate heat, applied to vegetable and animal matter, (saw-dust of

wood and horns of animals) subjected to compression, he formed a matter more or less bituminous*."

* Though so much has been stated on the vegetable origin of bituminous matter, it is not asserted, nor would the author insinuate, that animal substances may not contribute to the formation of it. All that is intended is, to shew that it is *chiefly* composed of *vegetables*, and almost altogether formed from the organized kingdoms of nature.

ESSAY VI.

ESSAY VI.

ON THE ALLIANCE BETWEEN PEAT MOSS AND ALL THE OTHER VARIETIES OF BITUMINOUS SUBSTANCES.

This alliance may be pursued still farther. Hitherto it has been traced only between peat and the concrete or solid bitumens. But the same train of reasoning will lead to the conclusion, that all other bituminous matter owes its origin also to the organized kingdoms of nature, and is nearly allied to peat moss.

This alliance will appear more obvious on the following account: 1. That if moss be composed of the ligneous and aquatic plants, already described, it contains an abundant quantity of the elementary principles of bitumen. 2. That there are in moss chemical agents, adequate to accomplish the changes and combinations requisite to the formation of bituminous matter. 3. That there are the clearest evidences that these changes and combinations are forming under our eye. 4. That all the varieties of bituminous matter have been detected already formed in peat moss. Each of these points is of importance.

And if they can all be established, the above conclusion will be corroborated; and the alliance between peat and every other species of bituminous matter elucidated.

The following Sections are, with this view, submitted to the public.

SECTION I.

That there are in Moss materials in abundance for the formation of bitumens.

The elementary principles of these substances are known. Hydrogen and carbon constitute the chief ingredients of all bituminous matter. Sometimes a portion of azote and oxygen enter into the combination. The latter, by its action on the other ingredients, makes the whole assume a more concrete and solid consistency. It, as the great acidifying principle, acts in producing that portion of peculiar acid which is obtained by a chemical analysis from these substances. No doubt other ingredients, and extraneous matter, enter into the combination in some cases. Argillaceous earth is frequently found incorporated with bitumen. But this is called by the distinct name of bituminous schistus. Metallic particles, by combining likewise, form all the varieties of bituminous ores. Earthy matter and carbon, entering into

the combination, form all the species of jet and coal. The ampelite, too, seems to be a bituminous matter of this complex kind. It contains a portion of argil, sulphur, and bitumen.

Hydrogen and carbon, however, may be considered as the chief ingredients of all bitumens, whether solid, fluid, or aeriform. That these abound in peat moss has been already shewn. But in order to the formation of bitumen, the carbon must be in a soluble state. It remains, therefore, to be proved, that a mass of vegetable matter, such as peat is supposed to be, contains a sufficient quantity of carbon, already prepared, to form new combinations with the hydrogen which abounds in it.

1. The carbon contained in the acids which exist in peat is already in a state of solution; and if set free from its combination with oxygen, it is prepared to enter into combinations with hydrogen, and form bituminous matter. That carbonic acid must have existed in all mosses, at one period of their formation, cannot be doubted. That there is a perpetual accession of it, during the whole process, seems highly probable.

But not only is the carbon, which this acid contains, already in a soluble state, but all that which exists or existed in the gallic acid, while the vegetable matter was in a recent state, must be of the same description.

2. The tanin, and in general, the whole vegetable extract which exists in the cellular membranes of

vegetables, likewise contains carbonaceous matter in a state of solution. By the continual maceration of these vegetables in water, there must, therefore, be a constant accession of soluble carbon. That carbon, when set free, must form combinations with the hydrogen. In this form it must be precipitated to the bottom of mossy lakes *.

3. It may likewise be noticed, that all moss water contains carbon in solution. It, of course, leaves a sediment by evaporation, which is inflammable, consisting of carbon and hydrogen. And, in low-lying level mosses, there must be a perpetual accession of it by alluvion; especially in such as lie in the vicinity of higher mosses, or declivities covered with that substance. The moss water, washed down, for ages past, by the rains and rivulets, being deposited and allowed to stagnate on the adjacent levels which contain moss, must thus have furnished a continual accession of carbon in a soluble state, since the first moment moss was formed †.

4. The essential oils of vegetable matter must furnish materials for the formation of bitumen. Hydrogen and carbon not only exist in every plant of which moss is composed, but they exist in the

* Probably it is by this means that the black pulpy moss, which is found in such situations, has been formed. It is, of course, as might be expected, almost utterly destitute of the organic structure of vegetable matter.

† See what is stated in Section I. of the third Essay on this subject.

combined form of the essential oils peculiar to each species. Hence they may be extracted, either by distillation or expression, from the recent vegetable.

The alliance between these essential oils and bitumen is obvious. Both have the same bases, and both contain the same elementary principles. The difference between them is therefore small.

These oils are convertible into resins. The difference between the former and latter is likewise small. The oils contain a greater proportion of hydrogen, and less oxygen, than the resins. This constitutes the chief difference between them, and the former may be converted into the latter. For, when oils are exposed to the influence of the atmosphere, they acquire the consistency and properties of resins. This change is effected by the absorption of oxygen. Of course, the more oxygen these oils absorb, they uniformly become harder and more compact. "Westrum exposed linseed-oil for five years to oxygen. In consequence of this, it was coverted into resin." He does not say that he added occasionally, during that period, fresh supplies of oxygen. Had this been done, the change might probably have been effected in as many months or weeks.

During the growth of vegetables, a similar process is perpetually going on. The hydrogen and carbon of the vegetable uniting, form essential oils. These, by an accession of oxygen from the air, or perhaps from the vegetable acids in the plant, are changed into gums and resins. And in proportion to the

quantity of oxygen that enters into the combination, these become more concrete. Accordingly, when they first exude from the plant, they are less compact, and frequently in a fluid state. During the heat of summer, they retain this appearance. But by exposure to the air, till autumn, they assume the concrete form of resins. In this form, they are found not only in resinous wood, but Senebier has observed them even in aquatic plants.

As oils may thus be converted into resins, so may both be changed into bitumens. When transparent oil of turpentine, which resembles naphtha in appearance, is mixed with a small portion of sulphuric acid, it is converted into a substance like petroleum. With a greater proportion of the acid, it assumes the black tenacious appearance of Barbadoes tar; and the mixture may be so adjusted, as to acquire the consistency of asphalt. In these cases, it is the accession of the oxygen in the acid that operates this change. That such a change has taken place in the resins, and gums, and oils, which exist in the vegetables of which moss and surturbrandt are composed, appears highly probable, from this circumstance, that a resino-bituminous substance (as has been stated) has been discovered in both.

On all these accounts, it is not surprising, that a substance similar to bitumen has been discovered in every species of peat, although none can be detected in a mass of the same vegetable matter which has been exposed to the atmosphere. The reason is ob-

vious. In this last case, a considerable, if not the greatest proportion of the hydrogen, and even a part of the carbon, must have been expelled in the form of gas. Stripped, by this means, of the elementary principles of bitumen, the residuum cannot be expected to contain it. Whereas, in the first case, the same vegetables, containing the same principles, and in the same proportion, while in their recent state, immersed in water as they are, wherever moss is formed, undergo no such changes. There is not a sufficient degree of caloric, or other agents, to expel the hydrogen nor carbon in the form of gas. There they must remain; there they combine; and there they form bituminous matter.

Thus the acids, the tanin, the whole extractive matter of vegetables, contain a proportion of soluble carbon. The oils, the gums, and resins, contain both hydrogen and carbon, not in a separate but combined state, already approaching to bituminous matter. But in order to elucidate the subject, it may be proper to shew,

5. That the quantity of these elementary principles, in all mosses, must be considerable, and in some very great. The proportion of these must depend upon the species of plants of which the moss is composed. All vegetables, whether ligneous or aquatic, contain vegetable acids; many yield tanin, and all an essential oil. To ascertain the proportion which a given quantity of vegetable matter may yield, would be a difficult and unavailing task. The gums and resins

of ligneous plants, and the quantity that they yield, may be more correctly ascertained, and furnish a more palpable argument on this point.

Some mosses contain a vast proportion of ligneous plants; and, of all the species, the fir-tree holds the first place. This is what might have been expected. For, in the ancient forests which abounded in the north of Europe, (which are supposed to have laid the foundation, and formed the first materials for the formation of moss), the fir-tree was the most frequent. We have the testimony of Pomponius and Pliny to this effect. They both describe the distinct species of trees which flourished in their days. And both agree, that the *abies* was not only the most frequent, but the most magnificent of all the trees of the forest.

It is of little moment which species of the fir-tree is found in moss. Nor is it of any consequence, whether the Pinus sylvestris, Scotch fir, has been discovered south of the Forth *.

* Cambden supposed that the Scotch fir was a plant peculiar to the north or cold climates. Dr Walker, in his Essay on Peat, expresses the same opinion. He says, that "there are no monuments of this species, even in the Lowlands of Scotland. That the remains of it are not to be found in any mosses south of the Forth."

Other authors have maintained an opposite opinion. Du Hamel says, that it is not peculiar to any climate. He thinks it probable, that it will grow in the frigid, temperate, and torrid zones. Lambert, in his description of the genus Pinus, shews that it does not grow in St Domingo, as was supposed by Du Hamel. He says, that it is the Pinus occidentalis of Swarts that is found in that island. Whether the Scotch fir has ever been found in the torrid zone or not, is of small moment. Both of

It is certain, that wherever moss has been discovered, fir-trees have been found. M. De Luc, who has had more opportunities of ascertaining this fact than most, perhaps than any man in Europe, says, that there is no exception to this general rule. In some mosses, vast numbers of the trunks and cones of fir are found. In the Philosophical Transactions, No. 275, the author says, that infinite millions of fir-trees are found through the whole extent of Lincolnshire Wolds, Gainsborough, Bantry, Doncaster, Balnsnaith, and Holden. He enumerates the different species that are discovered in that district. The very first that he names, as the most prevalent, is the pitch tree, commonly called fir.

A mass of vegetable matter, of this description, must, of necessity, contain an immense quantity of resinous matter. To give a rude calculation of this, the following facts are submitted to consideration.

these authors agree, that it flourishes in the frigid and temperate zones. This is enough for the present purpose. For it is in these chiefly, if not solely, that moss has been found.

And it is certain, that the remains of this species have been found in moss, much farther south than either Cambden or Dr Walker supposed. Dr Leigh, in his Natural History of Lancashire, &c. says, that the Scotch fir is not peculiar to Scotland. Immense trunks of that species have been found buried in the mosses and fens of Lancashire. He adds, that there can be no doubt of this, for the *cones* of that particular species are found, along with the parent tree. These trees appear not only to have existed and flourished in south Britain, but even on the continent, much farther south than Britain. Rozier asserts, that the Scotch fir grows on the mountains of Geneva, as well as in Scotland. On the mountains of Lyons, he says, it is also found. He describes the leaves and cones so correctly, that there can be no doubt of the species.

Du Hamel is an author of unquestionable credit. He has paid particular attention to this subject. In his treatise des Arbres, he mentions the following facts with regard to the fir-tree, and the quantity of resin which it yields. He states: "That it is extracted from them when young: That a single tree will yield from thirty to forty lib. weight every year: That this, in place of injuring, preserves the tree, as it would otherwise decay: That though this operation be repeated for twelve or fifteen years, the wood is equally valuable, as if no resin had been extracted."

He farther observes: "That the resin thus collected, does not at all proceed from the wood, but from between the bark and rind: That when it first exudes from the wound made, it is in a soft semiliquid state, but soon after becomes a concrete gummy mass, or excrescence: That the roots yield a greater quantity in proportion than the trunk, but this resin is more clotty and concrete: That the root continues to yield after the trunk has decayed: That the knots yield more than the trunk, and the trunk more than the branches: Thus a tree will continue to yield for thirty years, and even after it appears to be in a state of decay."

He adds. "That if, by any accident, a branch be broken off, or any wound made in a tree by bears or otherwise, it bleeds freely: That the savages of Canada, are aware of this: And as they collect pitch for economical purposes, they prefer such wounded

trees to others: That they dig a hole in the earth at the root of the tree to receive the resin. This hole is soon covered over with an incrustation, and by this means it becomes water tight, like a tub."

Now, if we take all these considerations into the account; if we consider the quantity of resin which a single tree of an ordinary size will yield; the prodigious age and size of some trees found in moss; the vast number that must have grown on a given space, where the forest was thick set:—if we consider, farther, the accidents to which they must have been exposed, by winds, thunder-storms, and wild beasts, during all the period of their growth; and especially at the period of their final overthrow, and that at these wounds they must have bled freely:—if we add to the account, that after they had fallen into ruins, and been stripped of their bark, the trunks and roots must have still continued to yield: and above all, if we consider that this process must have been going on, during all the period of their growth and decay, not of *one*, but in some cases of *two* or *three* generations; if we take all these considerations together, the quantity of resin deposited by such a forest in a given space, must be so immense as to exceed calculation. And the accumulation of hydrogen and carbon in such situations, must furnish abundant materials for the formation of bitumen. So that in place of being surprised, that any such substance should be discovered in moss, it would be matter of astonishment that it did not abound.

To all this it may justly be objected, that resins are insoluble in water. Therefore, though they contain the elementary principles of bitumen, yet these being in an insoluble state, cannot be converted into that substance, till they be reduced to a state of solution. There are, however, strong reasons to believe,

6. That the greatest proportion of the resins, which existed in the recent vegetable, has been in a state of solution, during the formation of moss. This will appear from the following facts.—No resins can ever be detected in moss, in their original concrete form, or in a simple uncompounded state.—Even fir-trees which must have contained a considerable proportion of resinous matter, are now partly robbed of it. They have uniformly lost their longitudinal adhesion; and the bark of these trees contains no greater proportion of resin, bulk for bulk, than the surrounding moss.—Nay, those aquatic plants, which, in their recent state, contain the smallest proportion of resin, are equally impregnated with a resino-bituminous matter, as the trees which, in their recent state, contained the greatest proportion. This is a presumptive proof that the resins had all become soluble, and thereby been equally diffused through the whole mass.—All moss water is impregnated with a resino-bituminous matter. Dr Hutton observes, that "when evaporated, it uniformly leaves a precipitate, resembling fossil coal." This is still a stronger proof, that the resinous matter in

moss is in a soluble state.—The subsoil of moss, though a solid tenacious substance, is frequently impregnated with this resinous matter, to a considerable depth. Of course, though it consist of clay, it is often highly inflammable. As the schistus which accompanies coal strata, partly partakes of the inflammability of that substance, so the clay which forms the subsoil of moss is often possessed of a similar quality. This is a strong proof that the bituminous matter of both has been in a soluble state.—A resino-bituminous matter has been extracted from Bovey coal, and the schistus which accompanies it is also impregnated with it. Taking all these together, no doubt can remain, that the resins which existed in the recent vegetable have become soluble, during the formation of both moss and surturbrandt.

But 7. There are strong reasons to conclude, that even the carbonaceous matter, which forms the *fibrous* part of vegetables, may, by long maceration in moss, be rendered partly soluble. For it is certain, that trees are often discovered in that substance, in a soft and pulpy state, and when these are diluted in water, part of the fibrous structure is dissolved in that liquid. The wood found in Bovey coal must have been at one period in this plastic state, and partly soluble. For the compressed appearance which it assumes, cannot, (as has been stated,) be wholly ascribed to mere mechanical pressure, unless by some chemical agents it had been previously softened. And if the most solid parts of ligneous plants are

found frequently in this pulpy state, there is reason to conclude, that the softer and more delicate fibres of aquatics must have much sooner undergone this change, and that the carbon they contained must have become soluble to a greater extent.

But the question still recurs, how have all these changes been accomplished? And by what chemical agents? How has the soluble carbon contained in the acids in moss been set free from its combination with oxygen? And how have the essential oils of the vegetable matter in moss been oxygenated, so as to assume a concrete form? Or how have the resins and even a part of the ligneous fibre of vegetables been rendered soluble?

These questions naturally occur. In order to reply to them, it may be added, that, according to the hypothesis uniformly advanced, there are chemical agents in moss adequate for all these purposes. To point out a few of these shall be the subject of the following section.

SECTION II.

What are the Agents in Moss which co-operate to the formation of Bituminous Matter?

This is a subject which it would require the talents of a distinguished chemist to discuss. The

author disclaims all title to this qualification. The reader, therefore, can look for none of the delicate touches and exquisite polish of a master's hand. A few hints is all that he presumes to offer.

1. That carbonaceous matter exists in a state of solution in the acids, and vegetable extract of moss, has been shown. Till this carbon be set free from its combination with oxygen, and precipitated, it is not likely that it can enter into such a combination with hydrogen as to form bituminous matter. It has, however, been stated in the third Essay, that on the surface of mossy lakes, this change may be effected by light. And it is probable, from what is stated in the same section, that phosphorus and sulphur may serve the same purpose in some mosses. In others the iron and other metallic particles, having an affinity to oxygen, and being soluble in all these acids, may form oxyds, and thereby occasion the separation of the carbon. This is the more probable, from this consideration, that all metallic particles discovered in moss are oxygenated, and are only discovered in the state of oxyds*.

2. The essential oils of vegetables must also undergo certain changes, before they can be converted into bituminous matter. It is probable, too, that before these changes be accomplished, these oils must become soluble in water.

* Sulphur and iron combined rob the carbonic acid of its oxygen. The carbon it held in solution must therefore be set free and precipitated.

The alkalies effect this change. They combine with oils and form a coagulum. And though these oils were not soluble in water in their original state, yet after their combination with alkali, they are changed into a liquid saponaceous mass, soluble in that liquid. By this means these oils being dissolved, may be diffused through the whole mass of vegetable matter. And as volatile alkali may be detected in *all* moss, and potass and soda in some, may not these operate as chemical agents on these vegetable oils, and render them all soluble?

It may justly be said, that the combination of alkali with oil may form a saponaceous matter, but not bitumen. To effect this change, other agents are necessary, and these are not awanting in moss. It has been shewn, that oxygen, or *any* acid operates this change. May not the vegetable acids, which abound in all moss, and the mineral acids which exist in many, by combining with the vegetable oils, convert them into bituminous matter? That this must be the result of such a combination, cannot be doubted. And that all these acids and oils should exist in peat moss without combining, is scarcely possible. More especially, when it is considered, that all the former are soluble in water, and that the latter may become so by means of their combination with alkalis.

Perhaps the saline substances detected in moss may co-operate in effecting such changes. Monsieur Guetard observes, " that when vegetables are immersed in water and perish, the salts they contain are dissolv-

ed. These salts," he adds, "operate on the oils of the plants, and by this combination form a species of soapy bituminous matter. Hence the unctuous appearance of some peat, as he supposes, may be accounted for."

3. The resins of the recent vegetable are still more insoluble than the oils. Yet it appears probable that they undergo solution before they are converted into bitumen.

Whether the alkalies that exist in moss be the agents in this case or not, it is hard to determine. It cannot, however, be doubted, that when they combine with resinous matter, it is rendered soluble, as well as the oils. Even amber itself, which is more insoluble than resins, is in some measure soluble in an alkaline solution. Fourcroy observes, "that if two pieces of it are immersed in a solution of potass, and afterwards heated, they may thus be made to adhere and form one mass." Hoffman says farther, "that, when reduced to powder, amber may be entirely dissolved, by being boiled in a solution of pure potassa. By thus combining together, they form a species of soap." Peat, which is more nearly allied to vegetable resin, is entirely soluble in potass, or even in volatile alkali. May not the latter have operated, in like manner, on the resinous matter of the recent vegetable in moss?

Even the acids which exist in all moss may cooperate to effect these changes. Mr Hatchett shews, "that the acetic acid acts as a solvent of gums

and resins, without altering their properties." Senebier found, "that the carbonic and gallic acids act in a similar manner. He says, that the former dissolves gums and resins in part, that the latter precipitates the gums and mucilage of plants, and renders the resins soluble." And no doubt can be entertained that the *mineral* acids found in moss operate still more powerfully. Concentrated sulphuric acid, poured on the powder of resin, dissolves it in a few minutes. It is true, that this acid is seldom found in this *concentrated* state in moss. But though weaker, and though it must operate more slowly, yet in the lapse of ages this change may be accomplished. Such a solution, when formed, will assume an oleaginous appearance. And the greater part of the resinous matter which has existed in moss, in all likelihood, has been in this state at one period of its formation.

4. Even the ligneous fibre of vegetables undergoes a similar change when exposed to similar agents. An alkaline solution operates on the hardest wood. When allowed to remain over it any length of time, the solution acquires a tinge, and the wood becomes blacker and softer. Sulphuric acid operates in the same way; but with more rapidity and effect. If these agents operate so powerfully on the hardest wood, is it not reasonable to expect that the leaves, and softer parts, must yield much sooner to their operation, and that the less fibrous structure of many aquatic plants must have been entirely destroyed by them?

If we can thus discover chemical agents in moss, by the operations of which the soluble carbon in the acids is set free, and the oils rendered soluble; nay, if we can find agents which may effect similar changes, even on the resins and gums, and fibrous part of ligneous and aquatic plants, by the operation of which, too, the carbonaceous matter contained in all of them may ultimately be reduced to a state of solution; we are less at a loss to account for the new combinations which it must enter into with hydrogen, to form bituminous matter.

But these agents operate but slowly. There are others, whose operation must be more rapid; and these may be detected in some mosses. By their operation, all the varieties of liquid and aeriform bitumens may be evolved from the vegetable matter it contains. For though the temperature of moss in general be so low, as to occasion little or no evolution of gaseous matter; yet if, by any chemical agents, a sufficient degree of heat be occasioned, it is obvious, in this case, that a process similar to distillation, on a large scale, must take place. And in some mosses, there are agents adequate to accomplish such a process.

6. Pyrites, may be one of those powerful agents *. That it exists in many mosses, and abounds in some, has been already shewn. It is a combination of sul-

* Pyrites is sufficient to disengage the bituminous oil from coal. May it not serve the same purpose in peat mosses? especially as they are generally in a moister state than coal.

phur and iron, and it may be imitated by art. When these two are mixed together in equal quantities, and formed into a paste by a little water, a high degree of heat is occasioned. Many have tried the experiment. That similar combinations have been formed in mosses, cannot be doubted. And it seems equally certain, that, by these means, a process in some cases similar to distillation, and in others, to combustion, has taken place.

Now, the changes which a mass of vegetable matter, or which moss undergoes in distillation, have been ascertained. In the first stages of that process, a limpid yellow oil like naphtha is evolved; and, as it advances, more carbon is evolved; which, by uniting with this oil, gives it a darker colour and more dense consistency. So that, during the process, it assumes all the appearance of naphtha, petroleum, and mineral pitch.

As a proof that pyrites may occasion a process analogous to the distillation of moss, the following experiment may be made. Take a quantity of soft pulpy moss, newly dug, and pour on it a small portion of sulphuric acid and iron filings; an effervescence immediately ensues; heat is generated, and a limpid oil rises and swims on the surface.

7. Even calcareous matter may contribute to occasion a considerable degree of heat, when it combines with the bituminous matter in moss. When a little unslaked lime is poured into a small quantity of pulpy moss, a considerable effervescence takes

place; the temperature is raised, and a pellicle of oil swims on the surface. This oil, in some cases, resembles naphtha *.

If, by these means, a sufficient degree of heat be applied to the vegetable matter of which moss is composed, it is obvious, that all the varieties of liquid bitumen must thereby be evolved from it.

SECTION III.

There are strong reasons for supposing, that similar changes and combinations are actually accomplishing by similar agents.

A VARIETY of facts might be mentioned in proof of this. A few only shall be stated. They relate chiefly to the lake of Derwent-water.

1. The waters of that lake experience occasional-

* That a similar process is carrying on by similar means, in mud volcanoes, is probable from this circumstance, that the matter thrown out of them consists of marly schistus, calcareous earth, and shining pyrites.

That similar agents are the cause of many warm springs, seems to be equally probable. The waters often hold calcareous matter in solution; and almost always contain a considerable portion of carbonic acid. They of course boil, even at a low temperature, such as 119.

And that the liquid bitumens are evolved by similar agents, from vegetable matter, appears not improbable. Surturbrandt is frequently detected in the immediate vicinity of bituminous lakes. And calcareous earth and pyrites almost always accompany these strata.

ly very considerable agitations. These occur when there is not the least breath of wind, or any other ordinary cause of agitation. The waves, thus occasioned, do not roll along the lake in the form of waving billows. They rise perpendicularly into mountainous heaps, as if impelled by some force from beneath. Hence these agitations are ascribed to what is not improperly called a *bottom wind.* When a boat sails along the lake, this wind strikes the bottom of it as if it had been dashed against a rock. A kind of rushing rumbling noise is heard at the same time *.

2. After these agitations, large masses of vegetable matter, (similar to moss) rise from the bottom of the lake. These swim on the surface for a time, like floating islands, and then sink again in the lake. By a letter from J. C. Curwen, Esq. M. P. I am informed, " that near the top of Keswick lake, a similar island appears and disappears occasionally. The substance of which it consists is also similar."

3. If a pole be pushed into the mass, three or four feet deep, a quantity of air rushes out. This air smells like gunpowder. When collected, it catches fire when a lighted candle is applied to it. Mr Curwen mentions, in his letter, that the same is the case with the floating island which he describes.

* Similar agitations have been observed on the ocean. Especially in the year 1755, when the earthquake was felt at Lisbon. Ships, too, though far at sea, and in deep water, seemed to strike ground. Similar noises have been heard.

These are the facts which have excited attention. The following remarks upon them are submitted; probably they may throw some light upon the subject.

1. It seems probable, that this lake was at one period a forest: hence the quantity of trees found buried in it. At a future period it appears to have been converted into a morass: hence the aquatic plants that abound in the mossy matter at the bottom of it. By some natural cause, similar to those mentioned in the Second Essay, p. 226, &c. the waters may have been so stemmed up, as to convert the whole into an extended lake *.

2. It appears also probable, that the mass of vegetable matter is exposed to some chemical agents, which excite occasionally a degree of heat in the whole mass. Pyrites may probably be discovered to be the cause of this; or, perhaps, a combination of iron and manganeze. Mons. Tingry observes, that in Derbyshire, there is a mixture of this kind, which spontaneously takes fire, when mixed with linseed oil. Subterraneous fires, he adds, may be produced by a mixture of oil or petroleum, with a similar ore of iron with that just mentioned. This is the more probable, as there are warm springs in the neighbourhood. Dr Short mentions, " that there

* Probably it may be no difficult matter, by a narrow inspection, to discover the cause of this change. Perhaps the outlet of the waters of this quondam forest or morass may have been choked up by some inundation, or the eruption of a part of some of the adjacent mountains. Those who live on the spot can best determine this.

is a tepid bath at Matlock, and that the springs above and below it are of the same temperature of spring water." Probably this *tepid* spring is connected with some stratum of pyrites, or magnesia and iron, or limestone rock. He says, indeed, "that, in digging a hole, he found a *black* substance, (he calls it croil), and limestone, which, being mixed together, produced five degrees of heat."

3. Now, when such mixtures are immersed in water, or moist earth, they occasion not only a considerable degree of heat, but an evolution of hydrogen gas, or sulphurated hydrogen. The latter smells like gunpowder; and, like the air evolved from the floating islands in Keswick, it catches fire by the light of the candle. Whether the lake Derwent-water, when agitated, rises in temperature, I have not heard. But it seems more than probable, that the gas emitted from these islands, is either hydrogen, or carburetted, or sulphurated hydrogen. And it is equally probable, that the evolution of these, from the whole mass of vegetable matter, when a sufficient degree of heat is applied, is the cause both of the vegetable matter swelling and rising to the surface, and of the bottom winds that agitate the waters.

4. When any mass of vegetable matter, impregnated with these gases, is exposed to a degree of heat, it expands, and becomes specifically lighter than water. Moss is of this description. And the floating islands mentioned above, are obviously homogeneous to moss.

In proportion, however, as these gases are evolved from such a mass, it becomes specifically heavier. It will swim therefore, for a longer or shorter period on the surface of water, in proportion to the quantity of this gaseous matter it contains. And when these gases are discharged, the mass will sink. This is precisely the case with these floating islands; some of them sink in twenty-four hours, while others continue to swim for weeks.

5. When an accumulation of vegetable matter or moss is exposed to such agents, and when such a degree of heat is excited, the whole must undergo a process similar to distillation, on a large scale; and by that process, all the varieties of bituminous matter contained in the mass may be evolved in the same manner, and in the same order, as in the laboratory of the chemist. The carburetted hydrogen is bituminous matter in an aeriform or gaseous state. The limpid oil is the same matter in a liquid state. And all the other oil which becomes darker and darker, according to the degree of *heat* applied, is still the same matter, with a greater proportion of carbon.

Thus, all the varieties of liquid and aeriform bitumens may be discharged in succession. And thus we may account for the naphtha, petroleum, &c. &c. which appear on the surface of bituminous lakes.

6. This is accordingly the process that seems to be perpetually going on. In warm climates, the carburetted hydrogen of vegetable matter is evolved in

a gaseous form. Of course, these morasses, though they consist of similar vegetable matter with moss, are not inflammable, or fit for fuel. Even in cold climates, a similar process is going on over the *surface* of all mosses. Of course, they are uniformly less inflammable than the under-strata, where no such process is accomplished.

The fluid bitumens are also evolved from the same materials, by a similar process. In some mosses, especially those that are pyritous, the bituminous oil is raised to the surface, as in the first stages of distillation. Instances of this have been well ascertained. Du Hamel describes one in France. "It is found in low marshy grounds, and was discovered by a *fat globule*, that swims on the surface of the water that issues from it. This globule contains a bituminous oil." And that it is evolved from the moss, and swims on the surface, by the pyrites, appears probable from this, that a great quantity of *sulphur* is discovered in the moss itself, and the ashes of it yield a great *proportion of copperas*; of course, when charred, it takes fire spontaneously, if exposed to moisture. "Mr Flavigney, describes a similar moss near the village of Anvè." Many other instances might be mentioned.

7. In the lake of Derwent-water, a similar process seems to be accomplished by similar causes. The gaseous matter is emitted from the mass of vegetables, in the bottom of the lake, at some times with such violence, as to occasion a current or bottom

wind. This rushing up through the water occasions those agitations on the surface which have been described. And were the degree of heat sufficient, not only the aeriform, but the liquid bitumen would rise and swim on the surface, as it does in other lakes. Besides, if this process were to continue, the vegetable matter would be robbed of all the inflammables it contains. It would no longer resemble moss, but vegetable mould.

If, on the contrary, the same vegetable matter were covered with an *impervious mass* of earth, as moss, in place of a *pervious* liquid like water, no such evolution would take place. These volatile particles would be confined, as in a close retort. There they must remain, and there they must form new combinations *. What these combinations are, we cannot precisely determine. For it is impossible to dive into the abyss, and survey the secret operations of nature. But we may reason from analogy; and that analogy is clear and decisive. The hydrogen being set free, must unite with the carbon. But in place of forming carburetted hydrogen gas, as it uniformly

* "Degner accordingly observes, that when the moss which forms a matting on the surface of the Dutch lakes is removed, the darry, or spongy moss in the bottom, rises up, and leaves a lake sometimes of 30 feet deep."

And that a similar process is going on in these lakes, as in Derwent-water, and similar gases evolved by these means, is probable. For he adds, "*unhealthy air is generated* by this means." Probably this is owing to the evolution of the same gases that are discharged from the islands of Derwent-water.

does, when a sufficient degree of heat is applied, and when this gas is allowed to escape, it must form an oleaginous mass, highly inflammable. That, by an addition of oxygen, which it may acquire from the water or acids that are incorporated with it, it must assume the appearance and acquire all the qualities of bituminous matter.

The sulphur, too, though set free, in place of flying off in the gaseous form of sulphurated hydrogen, must be confined. There it may form new combinations; uniting with the metallic particles, such as iron or copper, in a state of solution; it may form all the varieties of pyrites*.

* While such combinations are forming, and all these materials are in a state of solution, they must be fitted to enter into the pores of wood and other vegetables, though in their original organic form. Hence thus pyrites may assume the figure and appearance of the original plant, into the pores of which it enters.

The carbonaceous matter, too, which (like the bones of animals) forms the skeleton or fibrous part of vegetables, while in a soft and pulpy state, may be prepared to imbibe the bituminous oil, formed as described above. Being at last fully impregnated with it, the whole vegetable (as in Bovey coal) may be bituminated, and still retain the traces of its original organic structure.

The cellular membrane and softer parts of the tree, may, in some cases, be filled with pyritous matter, before the harder parts be bituminated. Hence the beautiful appearance of some specimens. A section of them exhibits internally a party-coloured appearance, as if composed of alternate rings of brass and coal.

Part of a tree may be exposed to such changes, while the other part is beyond the reach of their operation. Hence specimens have been found in Loch Neagh of the following description. That part of the tree, which stood in the lake, above the moss in the bottom, remained in its original state unchanged. What was lodged in the moss, though obvi-

These remarks are not only applicable to Derwent-water, but to all those lakes in which similar agitations have been discovered, and such floating islands have appeared*. These similar appearances may probably be ascribed to the same causes in them all. It is unnecessary to say, that in Loch Tay, similar agitations have occasionally taken place. Perhaps it contains a mass of vegetable matter, like to that which rises from the bottom of Derwent-water; and, in all probability, that matter is exposed to similar agents.

Whether Loch Neagh or Loch Sneagh have ever been occasionally agitated in a similar manner, I have not heard. Of this, however, there is no doubt, that they contain a vast congeries of vegetable matter in their bottom.

That many other lakes are similar to these, and exposed to similar agents, seems highly probable from this, that they never freeze, during the most intense frosts. This cannot always be ascribed to the depth of water in them. For other lakes, equally

ously a part of the same tree, was bituminated. While that which was fixed in the subsoil below the moss was *metallified*, or completely impregnated with particles of iron.

* The Darry, or Braak Torf of the Dutch, and the *Dryvend* Land or floating islands in Holland, are all similar to the island of Derwent-water. These islands rise from the bottom of lakes in a similar manner, especially in the heat of summer. It is not in Holland alone, that such phenomena take place. M. De Luc, in his letter, says, " that they are so common in the district of Wackhusen, that it is called the country of the *floating islands*."

deep, are frequently frozen over. Nor can it be attributed to the climate. For, in the same climate, and sometimes in the immediate vicinity, one lake may be found which is uniformly covered with ice every winter, while another is never frozen. This difference must be ascribed to such chemical agents as have been named, or to the degree of heat thereby generated.

SECTION V.

To similar causes, too, all warm springs may be ascribed*.

It is probable that most part of these springs are occasioned by similar chemical combinations with these above described; for pyrites is discovered in the vicinity of the greatest part of them. The Geyzers, in Iceland, seem to be exceptions. The waters of these contain neither sulphur nor iron on anysalis. Abbé Ordinaire, therefore, thinks that the heat of these springs must be ascribed to other causes. Most warm springs, as has been said, contain a

* Pliny delineates a number that were discovered in his days. And it appears that they continue for ages; for those which he describes still exist. The warm springs at Bath, too, were known and resorted to by the Romans. The remains of the baths, erected by that people, were discovered in the year 1755, at the depth of twenty feet below the surface.

considerable portion of carbonic acid. Of course, they boil and foam, though their temperature is not so high as boiling water, 212. Bath spring is of this description. Its temperature, though it seems to boil, is not above 119. Many of them discharge gas, similar to that which is contained in the floating islands of Derwent-water. It catches fire with a lighted candle. The spring at Vigan, in Lancashire, is of this description. Sometimes, too, a rumbling noise is heard, and a rushing wind issues from them. "This happened at Bosely, in Shropshire, in the year 1711. After a great hurricane, all the inhabitants in the neighbourhood were roused from their sleep at midnight, by an earthquake, accompanied with a hollow noise. Some of the boldest of the inhabitants ran to the little eminence from whence the noise seemed to issue. Water oozed out from the turfs. And when an opening was made by a mattock, it sprung up like a jet d'eau. When a lighted candle was applied, it instantly caught fire, and burnt with such fury as to consume large pieces of wood thrown into it."

This inflammable gas probably proceeded from some vegetable matter converted into moss, or bitumen, which had come into contact with the chemical agents below the surface. A process, therefore, similar to distillation in this case was carried on. And if a sufficient quantity of bituminous matter had existed on the spot, it is probable it must have exuded in the form of naphtha and petroleum. Many facts

lead us to conclude, that a similar process is actually going on in the bowels of the earth. Dr Darwin mentions one: "About a mile and a half below the iron bridge on the east side of the river Severn, in making a subterraneous canal in the year 1786, the workmen found liquid bitumen oozing from the mountain. In proceeding farther, they cut through small cavities of various sizes, from which this bitumen issued. From ten to fifteen barrels, each containing thirty-two gallons, were at first collected daily. The quantity, however, gradually diminished.

"Beneath the level of this canal, a shaft has been sunk through a grey argillaceous earth. Under this lies a stratum of coal, of an inferior quality, yielding little flame when burning, and leaving much ashes. Below this is a rock of harder texture; and beneath this a coal of an excellent quality is discovered.

"The superior stratum (he observes) seems thus to be undergoing distillation. The liquid bitumen, being by this means expelled through the porous roof, the coal is thereby rendered less inflammable. The roof of the inferior stratum being more compact, and exposed to a greater pressure, prevents this. Hence no bitumen exudes from it, and this coal is more inflammable."

He adds, "that over the coal-beds near Sir H. Harpen's, in Derbyshire, thin lamina of asphalt are found in some places on the surface of the earth."

In Italy and Dauphinè, and in India, aeriform bitumen often issues from the earth. It also catches

fire by a lighted candle. In coal mines the same gas frequently abounds; and, when kindled, occasions dreadful explosions and fatal accidents. In the vicinity of all volcanoes, a similar gas, and sometimes, if not for the most part, liquid bitumen issues from the earth. All these circumstances corroborate the idea that all the varieties of bituminous matter, whether in a liquid or aeriform state, are evolved by distillation, from the masses of vegetables, either partially or wholly bituminated, that come into contact with chemical agents which occasion a degree of heat sufficient to discharge them.

SECTION VI.

The phenomena that accompany bituminous lakes may also be considered as a proof of this. In all probability these lakes contain a congeries of vegetable matter similar to moss. This is certainly the case in the Dead Sea. Parkinson says, "that surturbrandt is found on the hills on the east side of it, where the bitumen is produced." He says, too, "that the smell of the stones in these mountains is similar to bitumen." How such masses of vegetable matter have been thus immersed, we may easily conceive from what we know. Abbé Ordinaire has shewn, "that mountains have been raised by volcanoes, where

none existed before. And lofty mountains have, by the same means, been sunk, and converted into unfathomable lakes." If such has been the fate, or origin of the Dead Sea, it is reasonable to suppose, that the whole forests and vegetable matter which existed on the former surface must have been sunk in the lake. By this means, materials for the vast collection of surturbrandt may have been furnished; and the bituminous matter, that is found swimming on the surface of such lakes, in all likelihood is evolved from this vegetable matter by a process similar to distillation. Hence all of them emit a similar gas, noxious to animals. The very name of the Dead Sea is supposed to have been given to it on this account. Hence, too, the waters of such lakes are bitter, and abound in bituminous matter.

SECTION VII.

Mud volcanoes also exhibit phenomena that are consistent with this hypothesis. Petroleum is generally found swimming on the surface of the springs in their vicinity. Much gaseous matter is also emitted from them. Sometimes they are agitated to a

high degree, and large ebullitions of matter are thrown out from them as from a volcano. In the year 1794, Pallas says " that 100,000 cubic fathoms of this matter was thrown out from one at Tamari. It consisted of a mixture of mica, marly schistus, calcareous earth, and sand, with some crystals, and pieces of shining pyrites. The gas emitted is so inflammable, that it catches fire with a lighted candle."

Abbé Ordinaire is of opinion, " that there is a mine of coal under this. And that the sea, by an eruption, occasions an expansion of the water, converting it into steam, which occasions these ebullitions on the surface and the evolution of this gas."

Perhaps the pyrites may operate, in this case, in the same way as it seems to do in warm springs, bituminous lakes, and some peat mosses. Probably the calcareous matter, which is uniformly found to abound in all such volcanoes, may co-operate to effect these phenomena. It is certain, that when it comes into contact with any of the mineral acids, a considerable effervescence takes place. That it has formed such combinations with the sulphuric acid is clear from this, that gypsum has been discovered in the mud of Macalouba in Sicily. The same calcareous matter coming into contact with petroleum, might occasion a similar phenomenon. When put into a mass of peat moss, which contains much bitumen, it occasions a considerable effervescence. The whole mass is agitated, and the temperature rises for

a time. A small pellicle of oil, too, like petroleum, rises to the surface, as has been stated already*.

Upon the whole, if the above facts be established, and the reasoning founded on them be correct: if there exists in moss an abundance of the elementary principles of bituminous matter: if it contain also chemical agents adequate to accomplish the changes and combinations requisite to the formation of that substance: and if similar changes and combinations are forming under our eye: above all, if a variety of the solid bitumens, as peat, surturbrandt, coal, and jet, can be traced to the same vegetable origin—it is surely not an unnatural or unphilosophical conclusion, that all the liquid and aeriform bitumens belong to the same class, are formed of the same materials, and bear a near alliance to each

* The only phenomenon that seems to be irreconcilable to this is, that the temperature of these volcanoes is low. In Macalouba, it was three degrees below that of the external air. For the thermometer sunk from thirty-three to thirty when immersed in the mud of this volcano. And in that of Tamari, no evidence of fire, or even of heat, could be seen.

In all probability, this low temperature exists only on the surface. Deeper down, there is every reason to expect a high temperature. The salts, too, which exist in this mud, may perhaps be the cause why the surface is cold. Even sea salt, which abounds in all these mud volcanoes, occasions, during solution, a lower temperature. Sal ammoniac, which must exist in all bituminous matter when dissolved in water, sinks the temperature of the liquid from sixty-eight to forty-two. It is true, that this only continues during the solution. But it may perhaps be found, that this process is perpetually going on, on the surface of such volcanoes.

other. At least, it seems more consistent with analogy, to ascribe them all to this origin, than to sources which are not known, and agents which have not been ascertained. None of the bitumens have been clearly shewn to be of mineral origin. And it is doubtful whether any of the oils can be traced to that source. On the contrary, all the oils, and by far the greatest part of bitumens, are clearly allied to the vegetable kingdom. To conclude that the whole are homogeneous, and of the same origin, is more consistent, than to suppose that part belong to the vegetable, and part to the mineral kingdom.

This general conclusion will be corroborated, and the alliance between the liquid and solid bitumens will appear in a clearer point of view, if it can be shewn, that all the varieties of liquid bitumens, from the purest naphtha to the coarsest mineral pitch, have been discovered in peat moss.

SECTION VIII.

The varieties of liquid bitumens are few; and the difference that exists between them is small. That difference does not depend on different elementary principles, for these are the same in all the varieties, but on the different proportions in which they combine. Those which contain the greatest propor-

tion of hydrogen, and the least oxygen and carbon, are the most liquid. Whereas the more oxygen and carbon they contain, the more solid they become.

The different colours they assume seem to be owing to similar causes. Naphtha is one of the purest. It is liquid, and nearly colourless; but when exposed to the air, and still more to oxygen, or those acids which contain it, this pure bituminous oil becomes darker and deeper in colour, and more dense in consistency, till at last it cannot be distinguished from petroleum. Petroleum itself undergoes a similar change by the same agents. When it is exposed to their operation, it, too, becomes still darker and more dense, till it assumes the appearance of mineral tar. Thus, these liquid bitumens are convertible into each other, by agents which may be ascertained. And as vegetable matter appears to be converted into peat, and surturbrandt, and coal, and jet, by one and the same process, so the purest and most liquid bitumens are convertible into the concrete. The gradation between the liquid bitumens is as obvious as that between the more concrete. And as it is difficult to draw the line between the different species of peat, surturbrandt, and coal, so it is equally difficult in the liquid bitumens. They graduate into one another by so delicate and imperceptible shades, that it is not possible to say where the one ends and the other begins.

If, therefore, *any one* of these liquid bitumens can be discovered in moss, this must be a presumptive proof,

that they are all of the same origin, and bear a near alliance to it. This proof becomes still stronger, if any one of them can be detected which participates both of bitumen and the recent vegetable oils and resins. For this shews that the process is already going on, though not completed. Whereas, if bitumen were always found in a fully formed state in moss, we might have some reason to suspect that it was a mineral substance, which accidentally incorporated itself with the vegetable matter of which that substance is composed. But this proof becomes nearly irresistible, and this alliance almost beyond a doubt, if not one only, but *almost all* the varieties of liquid and aeriform bitumens, are detected in moss. To shew that this is the case is the object in view in this section.

1. Carbonated hydrogen gas may be justly considered as a species of bituminous matter. It consists of the same elementary principles with the liquid and solid bitumens. The illustrious Dr Black accordingly classed it among these substances, and he called it by its proper name, bitumen in a gaseous or aeriform state.

That this may be detected in all moss by distillation or combustion, is so certain, that it were utterly superfluous to offer any proof of it.

This aeriform bitumen, if prevented from flying off in a gaseous state, and collected in a refrigeratory, may be converted into a pure bituminous oil, like naphtha.

2. Naphtha may be considered as the next order of bituminous substances. This also may be extracted from peat during the first stages of distillation. It is even found swimming on the surface of mossy lakes. The pellicle of oil which Dumain describes, and that which is found swimming on the waters of Hassel moss, are of this description.

"Giroud extracted, from a cubic foot of French peat, half a pint of liquor, similar in colour, consistency, and chemical qualities, to naphtha. The colour was yellow, approaching to brown. It was of a strong odour. When exposed to the air, it thickened and became of the consistency of tar. As it hardened, it became less soluble in water. And when it assumed the consistency of tar, it became perfectly insoluble in that liquid. Sulphuric acid, poured on it, formed a brown precipitate, which was a bituminous oil."

3. Petroleum is less fluid than naphtha. It contains more carbon, and is darker in colour. Some of the mosses of Northampton contain a portion of this. Dr Morton, in his Natural History of that country, mentions, "that there is a peat there, which, when newly dug, feels like butter; when dried, it breaks and snaps. It is then as hard as wood, and so tenacious, that it is with difficulty torn asunder. It is called Cæspes Bituminosus, as it yields a quantity of petroleum." The Ince moss, in Lancashire, is similar to this. Dr Hans Sloane says, "that it smells strongly of bitumen and petroleum, of which

it yields a great deal on distillation." The *creeshy clods* of Aberdeenshire are probably of the same description; and the mosses in the bottom of Loch Neagh, are certainly so. Dr Hales examined the waters of this loch: A pound weight of them, on evaporation, yielded a quantity of bitumen and petroleum *.

4. Next to petroleum, mineral tar may be ranked. It is still less fluid, approaching to solidity. A substance, similar in consistency and qualities, has been detected in peat moss. M. de Luc says, "that in passing through the moors of Breda, he saw, in the gullies of the mosses a black sediment, of the colour and consistency of pitch. When exposed to the air it hardened. By drought it cracked and rended, and curled up like little horns."

He mentions too, "that in the lands which form the subsoil of moss near Zell, pitch is found. It is collected in abundance by the inhabitants. They turn up a quantity of the sand which lies below the moss and mix it with water; they then jumble the two together. The sand, by its specific gravity, sinks, while the pitch swims on the surface and is thus collected." By another mode, equally simple, it is collected from the same sandy subsoil. "They dig a pit in the sand, and surround it with boards, leaving

* To these he ascribes the healing quality which this water possesses. It is not improbable that this may be the case. For petroleum has been used as a cure for wounds and cutaneous disorders.

small interstices between them. A brown grumous water oozes through these chinks. The sand it contains sinks to the bottom, while the pitch swims, and in this manner is collected."

He adds, "it is well known, that pine trees delight in a sandy soil. The probability is, that this pitch is the production of resinous wood of this species, which abounds in these moses. This resinous matter, however, is partly bituminated, and partakes of the qualities of mineral tar."

A similar substance is extracted from the Dutch mosses. Degner says, "that the odour of it is not so fetid as animal oil. It burns like spirit of wine; it is soluble in that spirit. He says, that it is a resino-gummous oil, or pitchy matter."

5. Asphalt is still more concrete, and approaches nearer to the solid bitumens than mineral tar. It is sometimes friable into powder, and often specifically heavier than water.

Cambden, in his Britannia, says, "that it also has been detected in many of the moss waters of England, especially in Shropshire." Leland, in his Itinerary, makes the same remark: "When this water is boiled, a kind of tar swims on the surface. When distilled, it yields an oil like petroleum. This proceeds from the pix mineralis (as Cambden calls it) which abounds in these waters."

6. Amber may be considered as still more solid than asphalt. Indeed it is equally so as the most concrete bitumens. There are, however, strong rea-

sons to suppose that it has once existed in a liquid state. The ants, and flies, and spiders, and vegetable matter found incorporated with it lead to this conclusion. Otherwise how could such extraneous matter ever have penetrated into the solid substance? This is still more probable, as it is sometimes found in the liquid state of amber oil.

In this state it is detected in moss. Dr Leigh, in his Natural History of Lancashire, mentions, "that it has been discovered in Hassel moss. It is a bituminous turf; it smells like oil of amber. The oil extracted from it," he adds, "is precisely similar to that, and answers all the purposes in medicine which amber oil serves." He says farther, that "this oil is often found floating on the surface of the water. That it is of a strong antiseptic quality, and preserves flesh. Woodward examined the waters of this moss. He says that, on distillation, they yield an oil of amber. It burns with a clear white flame, and is used in place of candle by the peasants. It prevents, or greatly retards, vegetation. Hence no tree nor shrub flourishes where it is found. It preserves raw flesh like a mummy*."

In Prussia, the finest amber is often found, not in a liquid but concrete state, in similar situations. Junker describes the Prussian mines, from which this substance is dug, in the following language: "On

* The proprietor of Hassel moss would do well to look after it. If the above account be correct, it may be of much value.

the surface there is a stratum of sand. Immediately below this is a bed of clay. Next to this a stratum of black earth or turf, filled with fossil wood, is discovered half decomposed and bituminous. Under this the amber is found in nodules, and sometimes in accumulated heaps." Hoffman makes a similar remark with regard to mines, from which amber is dug, near Fischausen. "The upper stratum is like that mentioned, a bed of sand. Under it, too, is a bed of clay; next to this is a stratum of wood, but inflammable; under this is a vitriolic mineral; and lastly, a bed of sand, in which a great quantity of amber is found." Helving makes a general observation to the same purpose. *He* says, that "*wherever amber is discovered, a bituminous earth, or fossil wood, is found.*" And it is his opinion that the amber resides in this wood. Alexander Sapieha says, "that it is sometimes discovered mixed with the cones of the Pinus abies: and, for the most part, it is accompanied with surturbrandt. And M. de Luc, speaking of the amber found along the shores of the Baltic, and the banks of the Elbe, makes the same observation. He then puts the following questions: "*Does not that which is found along the shores of the sea proceed from the continent? Does it not originate from the resinous wood buried in moss?*" Girtanner seems to be of a similar opinion as to the origin of amber. He supposes, that "it is vegetable oils, concreted by the formic acid. The formica rufa," he observes, "frequents the forests

of fir, where amber is found in a ductile state, like liquid wax. It only becomes solid when exposed to the atmosphere."

Fourcroy ascribes it to a similar origin. But he supposes, that the sulphuric acid operates the change, requisite to its formation from vegetable matter.

Monsieur Tingry supposes, " that this change is affected by mineral vapours. And that all the different degrees of liquidity and solidity which characterize the different bitumens, are owing to spontaneous decompositions, and new combinations, occasioned by these mineral vapours. In the silence of nature, and the revolution of ages, he supposes that an analysis of vegetable matter is effected, similar to that which takes place in a close vessel."

Though bituminous matter, of every description, has thus been detected in moss, it is not insinuated that all these varieties are found on the same spot, or that all mosses contain an equal proportion. On the contrary, one species of bitumen may be discovered in one moss, and another in another. One, too, may contain a large, and another a small proportion of that matter. This difference must depend on a variety of circumstances. A moss, for instance, which contains a vast proportion of resinous wood, must contain more bitumen than one entirely, or chiefly composed of oak or aquatic plants, although both contain the same quantity of materials. But this difference may even depend on other circumstances than the materials of which different mosses are

composed. In one, the process of bituminization may be, by chemical agents, carried on with more rapidity than another, though both consist of the same vegetable matter. One, too, may be of recent origin, and another very ancient. In the latter, all other circumstances being the same, the process must be more advanced, and the bituminization more complete than in the former.

Yet all mosses contain a greater or less proportion of bituminous matter. In some it abounds, as much as even in coal or surturbrandt. Du Hamel distilled a quantity of moss found at Hainault. "Three pound weight of it yielded no less than 16 oz. that is, one-third of its weight, of bitumen, similar to that which is extracted from coal." Probably some of those in England, such as the Ince peat, and that at Hassel, may contain an equal, if not a greater proportion than that at Hainault.

It is not, however, on the *quantity* of bituminous matter which moss contains, that the argument as to its origin depends. If all the varieties of liquid bitumen, from the purest naphtha to the coarsest mineral pitch, have been detected in moss, the alliance between them and the vegetable kingdom may be traced in an unbroken series, from the purest naphtha to the softest peat. Between these two extremes, however apparently distant, there is a clear connection. These two links of the chain are united, by intermediate links, each of which may thus be traced. And the conclusion that naturally follows,

is well expressed by that accurate and ingenious chemist, Mr Hatchett, "that bitumens owe their origin to the organized kingdoms of nature, and that there is almost unquestionable proofs that they are produced by the modification of some of the proximate principles of vegetables, especially of resins."

We may farther conclude, that there is an alliance between peat, the most imperfect, and the purest and most perfect bitumens.

That alliance is accordingly observed, and expressed by the same author, in the following words:

"Turf is well known to be composed of vegetable matter, such as the roots and twigs of plants, mixed with a portion of petroleum. Peat is the same, excepting that it contains more earthy matter; or that the vegetables have undergone a more complete decomposition. And every fact seems to demonstrate, that bitumen is the product of these vegetables which constitute the ingredients of peat and turf. That it is by a certain degree of maceration that the bitumen is formed. That this is occasioned by the boggy nature of the places in which they are found." He adds,

"That a portion of vegetable matter, undecomposed, mixed with petroleum, thus produced, forms all the varieties of peat and turf. And that according as petroleum or bituminous substances combine with various proportions of carbon and earthy matter, they form jet and coal, or bituminous schistus. With metallic substances they form bituminous ores."

SECTION IX.

Upon the whole, we may conclude that "there is no occasion to ascribe the formation of moss merely to the deposition of matter by wind or water, or to crystallization, or to congelation, or refrigeration, or to exudation and subsequent concretion, or to an accumulation of animal matter," (to use the *ironical language* of Dr Anderson) "but to an accumulation of vegetable matter by a process which is natural and obvious, and easily accounted for, and to the various changes and combinations which that matter has undergone, in the medium of water in which it has been immersed. And that all the varieties of liquid, solid, and aeriform bitumens, may be considered as allied to peat, and of the same origin."

To some, these resolutions, and changes, and combinations which have been described, may appear a complex, perhaps, a clumsy account of the subject. To suppose that the same materials in the same medium, should undergo such a variety of modifications, and assume such various forms, as to be resolved, first into their elementary principles, then to combine anew, and again to be decomposed, and again combine by double and treble combinations, may appear, to some, a very complicated hypothesis.

To such it may be replied, that changes equally great, and combinations equally complex, are continually going on, in all the chemical processes of

nature and art, with which we are acquainted. In germination, in vegetation, in fermentation, distillation, and combustion; in each of these processes, the same materials undergo similar changes, and form similar combinations, by the operation of similar agents.

In all of these oxygen is the great agent employed. It pervades the air, the earth, the water. Guided by the unerring wisdom of the Universal Lord of all, its operations are felt throughout all the kingdoms of nature. By the supply of this, the life of every thing that moveth is maintained. Were this one simple element withheld, all living creatures would cease to live; all moving cease to move. By this, too, all the chemical processes that are perpetually going on, in the animal, vegetable, and mineral kingdoms, are promoted. Remove this, there would be no respiration, no germination, no fermentation, no disorganization, no combustion. All these processes would be arrested, and at a stand; and the material world, *humanly speaking*, would become a stationary mass.

Thus, as the revolving orbs of heaven depend on two simple laws, gravitation and impulse, and never cease to obey them, so all the kingdoms of nature, in this lower world, are guided by laws equally simple, and equally irresistible, because they are the laws which the MOST HIGH hath enjoined. His omnipotent arm is perpetually at work in all places of his large and wide dominions. By agents, few in number, and simple in their nature, yet irresistible

in their operation, all the chemical processes in all the kingdoms of nature, however different and complex they may appear, are continually carried on.

This appears especially from the consideration of the foregoing sections. The same vegetable matter, which, in the temperate and frigid zones, contributes to the formation of moss, in warmer climates, furnishes all the varieties of liquid, and, in the bowels of the earth, materials for all the solid bitumens. The difference that exists between a lake or marsh, in the torrid zones, and a lake or moss in the frigid, though containing the same vegetable matter, depends on the degree of heat that is applied to the mass. And that heat, whether in the stages of fermentation, distillation, or combustion, depends on an accession of oxygen.

When there is a low degree of heat, little or none of the volatile particles of vegetables escape in the form of gas. When there is a higher degree, the hydrogen and oxygen unite to form water, and escape in the gaseous form of steam. In a higher still, the hydrogen, combining with the carbon, escapes in the form of carburetted hydrogen; or higher still, in that of a limpid oil; till at last, by an additional doze of heat, or the combination of more oxygen, more carbon is expelled, and then this oil assumes a darker colour, and more concrete form.

In the first stage, where little or no gaseous matter escapes, the whole mass of vegetable matter is converted into moss. In the second, and subsequent

stages, all the varieties of aeriform and liquid bitumens are evolved from the same materials, by the addition of heat, or accession of more oxygen.

Moss therefore, seems to be vegetable matter in an unconcocted state, or vegetable matter placed in the mighty retort of nature, before heat be applied. Naphtha, petroleum, and all the varieties of liquid bitumen, are the product of similar matter, during a process similar to distillation.

It may be considered as a corroboration of this hypothesis, that moss is only found, at least on the surface of the earth, in the temperate and frigid zones, or where a low temperature reigns. Whereas naphtha, petroleum, &c. are found only in the torrid zones, or warm climates, or in situations where the temperature is high. While moss covers vast regions of the north of Europe; in the south, that is, in Italy, Sicily, and Greece, or in similar climates, such as Persia, Syria, and the Indies, where no moss exists, there the liquid bitumens abound. Whereas, in temperate climates, where moss abounds, these liquid bitumens are seldom discovered, unless in situations where, by the operation of chemical agents, a considerable degree of heat has been excited, as in warm springs, and the neighbourhood of volcanoes.

Now, *there can be no doubt*, that similar ligneous and aquatic plants have flourished in all climates, and in all latitudes. It is not insinuated, that the very *same* plants have existed in all these different

temperatures, for different climates produce different vegetables. But ligneous and aquatic plants, of similar kinds, certainly have flourished in the frigid, temperate, and torrid zones. These plants, too, must have been subjected to a similar fate. Some forests must have decayed through age, or been cut, or burnt, or overwhelmed, by a flood, or been buried in the earth, by an eruption of a volcano. If any such forest has undergone this fate, materials must have been furnished in the torrid, as well as the temperate zones, for the formation of moss. Why, then, has none been discovered in such climates? and why do the liquid bitumens abound there?

The reply is obvious. Such a degree of heat has been applied as to occasion a process similar to distillation. It is not said that this heat depends on the temperature of the climate *alone*. That can only affect the surface. It must be ascribed to other causes and chemical agents: To such as occasion warm springs and volcanoes, even in colder climates. Nor is it asserted, that all such masses of vegetable matter have, in warm climates, been exposed to the same degree of heat. On the contrary, there appears every reason to suppose that the degree differs. Where naphtha swims on the surface of a bituminous lake, or marsh, probably the vegetable matter is in a lower temperature than where petroleum abounds; and in a lower still where petroleum than where asphalt abounds. In short, in proportion to the quantity of carbon that is evolved from any lake

or mountain containing such a mass of vegetable matter, it is reasonable to suppose, that that matter is exposed, in the same proportion, to a higher temperature.

The analogy of nature leads to this conclusion. For in distillation on a small scale, this is the case. And nature seems to be guided by the same principles on a large and a small scale*.

In distillation it is natural to conclude, from analogy, that the same products and the same process will be observed in the small retort of the chemist, as in the vast laboratory of nature.

Now, in the former the limpid oil of vegetable matter is discharged in the early stages of distillation, where a low degree of heat is applied.

In the latter, where naphtha, a similar product, is found swimming on the surface of lakes, it is probable that these have arrived to that precise degree of temperature which corresponds in distillation. If so, it is reasonable to expect that this naphtha will contain less carbon than petroleum. This is the case.

When the process of distillation advances a stage farther, more carbon is discharged. Combining with this limpid oil, it communicates a darker colour and more concrete appearance to it. The temperature of those bituminous lakes on which petroleum

* From the smallest crystal (scarcely visible to the naked eye) to the lofty columns of the Giant's Causeway, and the basaltic rocks of Staffa, Skye, and Hiembla, the same rule is followed in the process of crystallization and the same form is assumed.

or mineral pitch is found swimming, may be equal to this stage of distillation. In this case, too, we may expect *a priori* that these bitumens will contain fewer salts in proportion than the naphtha; because these salts are more volatile, and sooner expelled, than carbon. This, too, is precisely the case.

That a similar process is actually going on in such situations, appears highly probable. Several facts have already been mentioned, which tally with this hypothesis. One more may be named, though many others might have been added. In the Duchy of Modena, oil and bitumen are discovered in digging into the earth. The consistency of this oil is different at different depths. Near the surface, it is liquid; a few feet deeper, it is less so; deeper still, it is of the consistency of butter; and at a still greater depth, it is as solid and compact as pitch. From this account, it appears, that the deeper they dig, *i. e.* the nearer they approach the heat which occasions this exudation, the more carbon is found combined with the oil. This accords precisely with the process of distillation; and it is a presumptive proof that this process, or one precisely similar to it, is going on in the great laboratory of nature.

It may be added to all this, that if a sufficient degree of heat were applied to any moss, the result would be precisely the same as that which takes place in all warm springs and volcanoes. From all of these a gaseous matter is evolved, consisting of carburetted or sulphuretted hydrogen; from some of

them a limpid, and from others a more concrete oil appears trickling through the surface of the earth. And thus all the varieties of liquid bitumens are produced. The product would be precisely the same, if the same degree of heat were applied to moss.

The alliance, therefore, between the liquid and aeriform bitumens and peat moss, may be as distinctly traced, as between that and the more solid bituminous substances, such as surturbrandt, coal, and jet.

SECTION X.

The general conclusion to which all these facts lead, is, that peat, surturbrandt, coal, and jet, are all homogeneous, and may all be traced to the same origin: and that they are all formed of vegetable matter, by one and the same process. Even in the softest peat, that process is begun. In the more compact species, it is advanced a step farther. In surturbrandt, it is still nearer its completion. And in coal and jet, it is accomplished.

It appears probable too, that the liquid and aeriform bitumens are all the product of similar matter. That they are formed by similar means with concrete bituminous substances: That they are discharged by a process similar to distillation, on a large scale, in the vast laboratory of nature. That this process is

accomplished by chemical agents, some of which may be ascertained, and that the difference that subsits between these substances may be accounted for, however great it may appear to be. In a word, that they are all the varied modifications of the original elementary principles of the vegetable or organized kingdoms of nature.

This conclusion will appear less surprising, if it can be shewn, that the distinguishing qualities of peat moss are similar to those of bituminous substances. This is reserved as the subject of the following essay.

ESSAY VII.

ESSAY VII.

ON THE DISTINGUISHING QUALITIES OF PEAT MOSS.

The object of this essay is to point out the peculiar qualities of peat moss, which distinguish it from mould and every other species of vegetable matter.

If there be any quality in peat inconsistent with the hypothesis hitherto advanced, as to its origin, or if we cannot account for all these peculiar qualities by that hypothesis, the conclusions we have made must appear still doubtful. If, on the contrary, moss possesses no one quality, but such as might have been expected *a priori*, and such as may be accounted for, these conclusions must be corroborated, and the whole hypothesis must appear more rational and consistent. And if these distinguishing qualities be found to be the same with surturbrandt, coal, jet, and other bitumens, the alliance stated in the foregoing essay must appear still more clearly established.

In this point of view, it is of importance accurately to ascertain what are the distinguishing qualities of peat. This shall be my first object. It is of equal

importance to shew that these are the qualities that might have been expected, and that none of them are inconsistent with the foregoing hypothesis. To establish this on the solid foundation of facts, and the plain principles of chemistry, is the object in view in this essay.

SECTION I.

INFLAMMABILITY.

It is utterly superfluous to offer any proof that inflammability is one of the distinguishing qualities of peat moss. This is acknowledged by all, and denied by none.

It may, however, be proper to point out,

The high degree of that quality which some peat possesses. Some mosses, if once kindled, will burn for weeks or months with unabated fury. Dr Anderson says, that the fire drying the surface of the quick moss, penetrates deeper and deeper, till it sometimes goes six or eight feet deep before it stops. An instance of this is mentioned in my first essay, p. 44. at Sheouerbeck. When the inhabitants set fire to the morass, it burnt with such impetuosity as to consume every thing that came in its way. By the caverns and lakes that were formed by the conflagration, the morass was rendered impassable.

Even in the coldest climates, such accidents have taken place. Gmelin mentions one that occurred in *Siberia*. A village stood in a turf moor. On account of the marshy foundation, it was removed to another place. That the remains of it might be more easily destroyed, the inhabitants set fire to them. The flames communicated with the soil, which was inflammable, and occasioned great devastation. He says that he was an eye witness of the fact, and that the fire continued for *half* a *year*.

Nay, some mosses are so highly inflammable, that a spark, or flash of lightning, will set them on fire. Abbé Fortis mentions an instance of this, in Dalmatia. A fen, near the village of Ostrovizza, he says, was struck with lightning. Its bottom, being turf, burnt for a long time. The fire was only visible through the night. Yet it consumed the fen, and converted it into a black barren surface.

Some mosses have kindled spontaneously, and burnt with equal fury. Collinson, in his letter to Sir H. Sloane, says that this has been the case with the brooks in the vale of Goodcheap. The soil of these is mossy, and often under water. Yet in dry summers this soil sometimes kindles of its own accord. He compares it to the spontaneous fire that takes place in hay-stacks. And he observes, that it kindles, not on the *surface*, but about four feet *below* it, and immediately above the under water. This appears obvious, on digging to that depth. When the moss is thus stirred, it flames.

Tacitus mentions a still more remarkable instance in his Annals*, in the vicinity of Cologne. The fire (he says) *issuing* from the *earth*, consumed villages, corn fields, and advanced to the walls of the city. Neither rains, nor river water, could extinguish it.

Schookius says, that this species of combustion is not unfrequent in the peat pits of Germany, especially in dry warm summers. Watchmen are, on this account, appointed to go round in such seasons, and be in readiness to extinguish the conflagration. This is done by smothering up the fire with earth, the moment it is first discovered. If this is not done, it rages for weeks, or even months †.

This high degree of inflammability is considered by some as *altogether inconsistent with the hypothesis hitherto advanced.*

Both Degner and Dr Anderson consider it as an insurmountable objection to that hypothesis. The former states this objection in plain and positive terms. He says, that it is, in his opinion, " contrary to physical facts, to suppose that peat is formed of decayed wood. That all vegetable oils are pure, and remain always inflammable. That they are the co-

* Lib. XIII. Ch. 57.

† The subsoil of moss, though a stiff clay, somtimes partakes of this inflammability, and burns with irresistible fury. An instance of this occurred in this neighbourhood. A moss being set on fire, not only burnt, but communicating with the arable land, kindled it, and continued to burn along the clay soil with fury. Had not ditches been cut to arrest the flames, it is hard to say how far they might have advanced.

hesive principle of all plants, and preserve them from putrefaction. But if these oils in wood, or other plants, be lost by lapse of time, so that the plants become carious and *putrid*, then they are dissolved and changed into a fat, pulpy earth, *not inflammable*, but fit for manure." He adds, "that the inflammability of wood and other vegetables is destroyed by *putrefaction*, and the plants reduced to a *caput mortuum*, unfit for *fuel*."

The latter states this objection in still stronger terms, and more eloquent language. He takes notice, first, of the high degree of inflammability which some mosses possess: "That it exceeds that of any kind of wood he has ever seen, and certainly, for the brightness of its flame, and durability of its charcoal, it far exceeds that of any small vegetable substance that is known."

He then, proceeds to shew, that this quality is unaccountable by, and altogether irreconcilable to the idea, that moss is vegetable matter. His words are, "It is well known, that when vegetables have once fallen into a state of *putrescency*, their inflammability decreases, in proportion as that *putrescency* augments. Yet, as moss becomes more *putrid*, it becomes more *inflammable*, which is directly the reverse of every well known progress of nature, in every other case." He adds, "were such arguments to be admitted in physics, there would be an end of all reasoning entirely. For it is an insult upon reason to say, that you are to argue from analogy, while you

go directly contrary to every known law in nature, that ought to constitute that analogy." This is not all the amount of his objection. He adds, "That wood in moss, after it has been *rotten*, does, in fact, imbibe from the moss, in which it is imbedded, something which communicates to it, on some occasions, even a greater degree of inflammability than it possessed in its recent state." This stumbles the Doctor still more. Hence he adds: "To suppose that a *rotten* branch of a tree should communicate to every inch of moss around it, perhaps ten thousand times its own dimensions, a greater degree of inflammability than itself ever possessed, and that too after it had lost its own inflammability entirely, is an hypothesis so *supereminently extravagant*, as requires only to be *pointed out* to be *reprobated*."

Thus, the inflammability of peat presents to him an insurmountable objection to the doctrine of the vegetable origin of that substance. "How vegetable matter should preserve this high degree of that quality, after undergoing *putrescency*, as he calls it, and decomposition, by *soaking for ages in water*, seems to him totally *unaccountable*." He therefore observes, "that if we were to attempt to preserve any kind of small vegetable, soaked in water, for perhaps *one thousandth part* of the time in any other situation, it would be reduced to perfect earth, and be no longer susceptible of *the smallest degree of inflammability*." The conclusion which he draws from the whole, is expressed in language equally bold and unqualified.

"It is therefore impossible for any human being, who spends but a single thought on the subject, not to be satisfied that, to whatever cause we are to ascribe the origin of moss, *it cannot be to the accumulation of vegetables* which have grown on its surface, now in a state of decay."

The learned Dutchman and ingenious Doctor are therefore at one on this point. The objections of both are fairly stated. The language of the latter is bold. He states the facts on which his objection is founded with his usual candour, for the purpose of future investigation. He challenges that investigation. With diffidence I accept the challenge, and enter on the investigation.

In reply to both the above gentlemen, it may be observed, in general, that if the hypothesis advanced in the foregoing essays be correct, their reasoning is founded on a mistake. Both speak of the *putrefaction* of peat. Both suppose that moss, like vegetable matter, when exposed to the atmosphere, and the alternations of moisture and drought, heat and cold, undergoes the *putrid* fermentation. Both argue that, on this account, it must have lost its inflammability.

It has been shewn in the Third Essay, that no such process has been accomplished in moss, excepting perhaps, on the surface, or in warm climates; that the inflammable ingredients of the original vegetables therefore remain, as few or none of them are evolved in a gaseous form.

And it may be proper to add, that there must be a continual accession of these inflammable ingredients, even when this vegetable matter is soaked in water for ages. That the inflammability of moss, in place of being diminished, or thereby destroyed, must be augmented in the lapse of ages; that, therefore, however great the degree of that quality may be in some mosses, this is in no shape irreconcilable with the idea, that all moss is of vegetable origin. That the highest degree of inflammability any moss *ever* possessed, may be accounted for on that hypothesis.

It is readily granted that some peat is more inflammable than the recent vegetable of which it is composed. Nay, it is farther granted, that some are even more inflammable than the Doctor has supposed, though some have doubted this *.

Another concession may be made, that the putrid fermentation does indeed diminish the inflammability of vegetable matter. And that this inflammability is diminished in proportion as the putrescency advances.

* Mr Nasmith seems to think, that inflammability is a property which peat possesses *in common* with other organic bodies of the same origin. He adds, that those who suppose that there is any thing extraordinary in its inflammability, have been led into a mistake. He doubts, therefore, of the propriety of its being called *Geanthrax*, or *coal of earth*. If, however, coal itself be called *Lithanthrax*, or coal of stone, with equal propriety may peat be called *Geanthrax*. For it certainly possesses a greater degree of inflammability than other organic bodies of the same origin. And there can be no doubt, that, bulk for bulk, and weight for weight, some peat possesses more inflammability than the very vegetables of which it is composed, in their recent state.

But it is by no means *proved*, that peat moss has undergone the putrid fermentation. It seems, on the contrary, clear and unquestionable, from the facts stated in the Third Essay, that the chemical agents adequate and necessary to accomplish that process, cannot combine with the vegetable matter it contains in the medium of water, in which it is placed. And that in this medium there is (as has been hinted) a continual accession of simple inflammables, and an accession too, by this means, of new and compound inflammables, formed by their combination. That, therefore, the longer the moss lies soaked in water, it must acquire higher degrees of this quality.

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1. *There is, in moss, during its formation, an accession of the simple inflammables.*

Hydrogen, sulphur, carbon, and phosphorus, are the simple subtances which are denominated inflammables. All of these exist, or abound in moss.

Hydrogen exists in every vegetable, of which that substance is composed. It is one of the elementary principles of all the essential oils, gums, and resins. Immersed deep in water, or moss, where a low and equable temperature reigns, little or none of this hydrogen assumes the gaseous form, or is evolved in that state.

Nay, if it be true that aquatic plants, such as flourish in marshes and moss pits, as Sennebier has said, "emit oxygen, and absorb hydrogen," by this means, there may be a perpetual accession of

this simple inflammable in all such situations. Or if it be found that phosphorus or sulphur decompose the water, (combining with the oxygen, and setting the hydrogen at liberty) even the water itself may thus furnish inflammable matter. And, by this means, a mass of vegetables, immersed in that liquid, may become more and more inflammable, the longer it is soaked in it.

That hydrogen is one cause of this quality, in all compound inflammables, appears obvious. For the more they contain of it, the more inflammable they become. Naphtha contains more than petroleum, of course it is more inflammable. Cannel coal contains a greater proportion than any other species, it, therefore, yields more flame than any of them. Blind coal contains the least proportion, and therefore burns with difficulty, and without flame. The same is the case with peat moss. Its inflammability, like bituminous matter, seems to depend, in a great measure, on the proportion of hydrogen it contains. Hence it, like them, becomes less inflammable, in proportion to the quantity of that gas that is evolved from it, and the proportion of oxygen it imbibes. Like them, too, for this reason, when long exposed to the external air, it loses its inflammability altogether. That is, when it is saturated with oxygen, it will not receive a greater dose; in other words, it is robbed of this peculiar quality. Hence, all peat on the surface, and all coal at the outburst, contains

least hydrogen, and is less inflammable on this account than the rest*.

There is, therefore, strong reasons for concluding, that hydrogen is one cause of the inflammability of peat moss, and that that substance, by being soaked for ages in water, may, by an accession of this simple substance, become more and more inflammable.

Sulphur is another simple inflammable which exists in all, and abounds in some mosses. The same remarks may be applied to it. Immersed in water, while the temperature continues low, as is generally the case in deep moss, it cannot assume the gaseous form. On the contrary, by a continual accession of fresh vegetable matter, and the maceration and consequent decomposition which it is continually undergoing, there may be a continual accession of sulphur. And in the same proportion, the inflammability of the moss may be increased, by being soaked for ages in water. Of course some mosses contain a great proportion of sulphur. Henckel observes, that he has seen a marsh, the surface of which was covered

* Oxygenation, distillation, and combustion, of either of these substances, are similar processes. They operate, too, in a similar manner. They differ only in the rapidity with which that process is açcomplished. Oxygenation is slow, distillation more rapid, and combustion is still more so; but in all of them, there is a dissipation of hydrogen in a gaseous form, and an absorption of oxygen. Yet the process may be fully accomplished by all of these. By the first, it may be completed in a course of months or years, as much as by the last in as many hours. In all of them, the inflammability is destroyed by the dissipation of hydrogen.

with powder of sulphur. And Dupuget observes, that the peat dug in the valley de Somme, has not only a sulphureous smell while burning, but sublimated sulphur may be seen by the naked eye in the crevices of it.

That this is another cause of the inflammability of most mosses, and of the high degree of that quality which some possess, appears from this, that they not only emit a flame similar to that of sulphur, but burn with such fury, that it is with difficulty they can be extinguished by water, though immersed in it.

Carbon is another simple inflammable which abounds in moss. Indeed it forms the chief ingredient of the best peat. And the inflammability of that substance depends, in a great measure, on it. For decayed or decaying vegetables, only lose their inflammability by the destruction of carbon.

This requires time, even in the medium of the atmosphere. Immersed in water, it cannot take place at all. For, in a low level, like moss, though this carbon may become soluble, it is not carried off by alluvion. And in such a low temperature as generally prevails, it cannot assume the form of gas.

On the contrary, there must be of this, as of the inflammables mentioned already, a perpetual accession. That is occasioned, not merely by the accession of fresh vegetable matter, but by the precipitation of the carbon contained in the soluble extract, the vegetable acids, oils, gums, and resins of plants. By this means the whole moss, especially the bottom

or under strata of it, may become more inflammable by being soaked in water.

It is almost unnecessary to observe, that *phosphorus* is another inflammable which exists in some mosses. And that, in proportion as the decomposition of the vegetable matter it contains advances, phosphorus must more and more abound.

But it may be proper to add, that if the above be a correct view of the subject, it must be less surprising that some mosses should be more inflammable than the recent vegetables of which they are composed, and that the longer they remain soaked in water, they are more and more inflammable.

Especially when it is added,

2.—*Secondly, That, by these simple inflammables combining together, they may occasion a constant accession of compound substances, which must cause a higher degree of inflammability, the longer that they remain soaked in water.*

Hydrogen and sulphur form a compound combustible. Both exist in moss. The former dissolves the latter. If, therefore, they ever come into contact, as they must do, a solution of the sulphur must be the consequence. A new combination must take place; sulphurated hydrogen must be formed. Hence most of the mineral waters of moss are impregnated with it. They of course smell like rotten eggs. Hence, too, the fetid odour that is felt, when mosses burst their barriers, as at Solway, Charleville, &c.

Hence the sulphur that may be detected by the naked eye, on the surface of the soil which they formerly occupied. And hence the inflammable air, emitted from the floating islands of Derwent-water and elsewhere.

Now, if there be a continual accession of these two simple inflammables in moss, there must be a proportional accession of the compound which they form. And as there is little or no evolution of that compound, in such a situation and temperature, in the form of gas, the moss must become more and more inflammable, by being soaked in water.

Phosphorated hydrogen is another compound combustible; it is formed in a similar manner. The hydrogen dissolves the phosphorus. These, combining together, form a compound, which, of all inflammables, seems to possess the highest degree of that quality. It spontaneously kindles when it comes into contact with the external air.

Hence, it may be often seen, in fens and mosses, in this state of ignition. The *ignis fatuus*, or Jack with a lantern, (or, as it is called in Scotland, *Sponky*, or *Will o' the wisp*), is phosphorated hydrogen in this state of spontaneous combustion. Hence it is often emitted from lakes and springs, appearing like a lambent flame on the surface of the water. Hence, too, it appears on bituminous lakes The asphalt, which rises out of these lakes, sometimes takes fire, when it reaches the surface, and explodes with a noise like gunpowder.

This gas abounds so much in many mosses, that, in walking over the surface in a dark night, it appears, and seems to kindle at every footstep. And if the surface be agitated, or stirred, it will seem to be all on fire. This is a species of inflammable compound, which cannot exist in recent vegetables of which moss is composed. It may be one cause why the latter, in some cases, is more inflammable than the former.

Hydrogen and carbon form a compound combustible. These are the elementary principles of all the varieties of bituminous matter. Having a strong affinity to each other, they must, of course, combine, as has been shewn in Essay III. As there is a continual accession of these simple inflammables, so there must be of the compound which they form. And in proportion to the greater or less degree of heat that is applied to the moss, in proportion too, as these simple ingredients combine, or are mixed with extraneous matter, must these combinations appear more or less pure, liquid, or solid; but always inflammable. Hence, all the varieties of bituminous matter have been discovered in moss. Naphtha is found in some; petroleum in others. Asphalt in some; amber in others. And hence, on distillation, every species of moss yields a certain proportion of bituminous oil, more or less concrete. And all moss whatever yields a considerable portion of carburetted hydrogen, or bitumen in a gaseous form. Hence even some peat yields one third of its weight of bitu-

minous matter in a liquid state, independent of what escapes in the form of gas. That such peat should be more inflammable than the recent vegetable of which it is composed, it is therefore reasonable to expect. For Du Hamel states, that a fir-tree, when fresh cut, in full vigour, yields only one fourth of its weight of tar; and that ordinary wood, yields only one twelfth. Whereas, Dumain extracted from the peat he describes, one-third of its weight of liquid bitumen. Probably the Ince peat may afford an equal proportion.

Besides this, it appears absolutely certain, that a considerable part of the bituminous matter in moss is in a state of solution; that moss water is almost always of the tinge of coffee; that when evaporated it leaves a sediment similar to bitumen cannot be doubted. If so, this may, of itself, account for the very high degree of inflammability of all *low lying level* mosses. For in all such situations, there must be a perpetual accession of this inflammable matter by *alluvion*. The moss water issuing continually from the mosses that lie on rising grounds, and especially on the acclivities adjacent, must thus be carried down to such low levels. There it must stagnate; there, too, it must continually deposit this inflammable sediment.

This simple, but certain process too, must have been going on, not for a season or an age only, but from the period in which moss first commenced its growth to the present moment. And it must con-

tinue as long as moss exists, or heath continues to grow on such declivities. For it has been already stated, that rain water, falling on heath, leaves a similar sediment, possessed of similar qualities. And M. De Luc has noticed (what every inquisitive careful observer may see in similar situations) that the water which descends into the plains of Twickle is impregnated with a black substance, which communicates the colour of coffee; and that, when it stagnates, there it leaves a sediment, which, of itself, becomes very good moss, from which the inhabitants dig peat.

To every low-lying level moss, liable to be overflown with moss water from the adjacent declivities, a similar accession of inflammable matter must be made. In such situations, therefore, we might expect *a priori*, that the longer such mosses were soaked in water, the more inflammable they would become. Hence moss is more inflammable in proportion to the moisture it contains. Hence too, the under strata are more inflammable than the superior. Hence water may be said to be the mother of peat as well as coal.

There is still another consideration to be taken into the account. Wood is frequently found in moss, in a soft, pulpy, and porous state. Dr Anderson takes notice of this: " I have seen a peat spade penetrate, with the utmost facility, a piece of wood as thick as my leg, which, if decayed to an equal degree in any other situation, would have been totally incombustible; yet this wood, when dried, was equally in-

flammable as if it had been quite fresh and dry, within a twelve month after it had been cut down."

To this it may be replied, that wood is often found in this case more inflammable than in its recent state; and yet this is no more than what might have been reasonably expected, though it is stated as an insurmountable objection to the hypothesis hitherto advanced in these essays. For, if wood be in this soft plastic state, it is reasonable to suppose that the bituminous matter held in solution in moss water would enter into every pore of the tree, and occupy the tubes which formerly were filled with the vegetable extract, the acids, the oils, and resins. Thus impregnated in every part with inflammable matter, deposited in this manner, the whole tree may become bituminated and much more inflammable than in its recent state. Parkinson accordingly observes, that moss wood is generally more impervious to water than the same species in other circumstances. This he ascribes to the bitumen with which it is impregnated. And it is unnecessary to repeat it, that, in Loch Neagh, and many mosses, and in Bovey coal, trees have been found *completely bituminated.*

Even oak wood has been found in this state. And if so, it must be greatly more inflammable than when lately cut and dried. For though dried, it must contain a considerable portion of the vegetable acids*, which, in place of being inflammable, extin-

* That these acids are soluble in water, it were superfluous to prove. But that they are dissolved in a very short period, when soaked in that

guish fire. Whereas, by being soaked for ages in water, it must be robbed of these; and their place being occupied by this bituminous matter, the whole must become more inflammable.

But if the hardest wood has been detected in a pulpy state, and the most compact completely bituminated, is there not every reason to conclude, that the softer and less solid species, and the still more delicate and tender leaves, and branches, and roots, of aquatic plants, must have much sooner yielded to the same agents, and been reduced to this pulpy state? And is there not the same reason to conclude, that they have been more easily impregnated with this bituminous matter? And can it then be deemed so supereminently absurd, to suppose that all this mass of vegetable matter should retain its original

liquid, may appear less obvious. Dr Watson, however, has established this fact, by a variety of experiments. He found that the hardest and most compact wood, lost part of its weight, after being steeped in water for 110 days, and dried in the sun for a month. Box, oak, and ash, lost one 32d part. Mahogany, walnut, and deal, lost only a 60th part. Now, the vegetable acids are one great cause of the relative weight of wood. The greater proportion of these which any species contains, the more solid, compact, and heavy it is. When robbed of these acids, its weight is of course diminished. It is probable, that the first three species contained a greater proportion of acids than the last. Of course they were more diminished in weight. And they must, on this account, have become more inflammable when robbed of these acids, than in their recent state. But if they had been immersed in water for as many years or ages, and if that water had been impregnated with bituminous matter, in a state of solution, and if that matter had entered into, and filled up every pore of the tree, as has been the case in all wood which is completely bituminated, can it be doubted, that it must have become much more inflammable than in its recent state?

inflammability, nay, acquire additional degrees of that quality, by being soaked in water for ages?

But though this accession of simple and compound inflammables may account for the highest degree of inflammability which Degner and Dr Anderson have supposed some peat to possess, it appears, from the foregoing sections, that some mosses are even more inflammable than either of these learned gentlemen have imagined. For it is beyond a doubt, that some spontaneously take fire, though immersed in water. And these simple and compound inflammables cannot account for this.

It may be added, however,

3. *That there are combinations in some mosses, which may account for their kindling spontaneously.*

Some of these combinations have been mentioned in Essay IV. Pyrites, or certain combinations of sulphur and iron, or of iron and manganeze, may occasion such conflagrations as have been described. That the former of these abounds in many mosses, has been established beyond the possibility of doubt. And that it is *only* in *such* mosses that this spontaneous combustion takes place, appears highly probable. The following facts may perhaps tend to elucidate this point.

1. That in those cases in which mosses kindle of their own accord, the conflagration does not commence at the *surface*, as it would do were it kindled by an accidental spark, or flash of lightning. Hence, in

the case mentioned by Collinson, at the vale of Goodcheap, the fire did not appear on the surface, but four feet *below* it. This is a strong presumptive proof that it was occasioned by pyrites.

2. Without a considerable degree of *moisture*, no such conflagrations take place. Hence Collinson observes, that this fire breaks out on the surface of the *under water*. And Flavigney makes a similar remark with regard to the moss near Anvè. It is only when it is put up into *heaps*, with a considerable degree of *moisture*, that it kindles of its own accord. This is a clear proof that this conflagration differs from common fire. It is also a proof that it is owing to pyrites, for it is only when moisture is applied that pyrites occasions combustion; and moisture, in place of extinguishing, excites this species of conflagration. Hence Tacitus observed, that neither rain nor river water would extinguish the fire in the fens of Cologne.

3. Sulphur may be detected in all those mosses which spontaneously kindle. Du Hamel accordingly describes a moss of this kind in France, in the following terms: When burning, it emits a sulphureous smell, and thick smoke. It burns, too, when *moist*, with a a slow singeing fire, without flame. It is of a caustic quality, and burns the hands of the workmen when handling it. The ashes of the peat retain this caustic quality. Such mosses are only found in *low marshy* grounds. And this species was discovered by a fat globule of oil, that swims on the surface of the water that issues from the moss.

4. The ashes of such peat uniformly contain the *sulphat of iron* or copper. In some of them a vast proportion of this salt is found. That which Du Hamel describes above, contained the sixth part of its weight of copperas. For he says, that three pound weight yielded half-a-pound of that salt.

5. The smoke of this species of moss, when burning, is fatal to animals. Bomare mentions that this is the case with the pyritous peat of Beauvois. It emits a stinking sulphureous smell. Of course, it is never burnt but in winter, as it would become an intolerable nuisance in summer. He observes, that sulphuric acid and sulphurated hydrogen are probably the cause of this.

6. Sulphur not only appears in the crevices of such peat, while burning, but it may often be detected on the surface of the moss itself, as an efflorescence. The late Professor Robison says, that this is the case in many of the Russian mosses. I have seen, says he, three places in Russia, where there is superficial peat moss, and in all of them, the vitriol is so abundant as to effloresce. One, in particular, near Petersburgh, shews it every morning on the clods, when the dew has dried off.

7. After such conflagration, the surface of the moss is uniformly a black *barren waste*. Not the smallest tendency to vegetation can be traced. No species of plant whatever will strike root, or vegetate on it. This is doubtless owing to the superabundant quantity of the sulphat of iron or copper that exists

on the surface. For, though a small proportion of these salts be a powerful manure, they are utterly deleterious when they abound. Abbé Fortis mentions, that the surface of the marsh in Dalmatia, which spontaneously kindled, became *utterly barren*.

8. When such mosses are charred, they spontaneously take fire, if exposed to *moisture* and air. Fourcroy mentions an instance of this, which took place in a timber-yard at Paris. Being filled with charred peat, and exposed for some days to rain, it exhaled a white smoke, which soon changed into flame, and the whole charred peat was consumed, threatening, every instant, the conflagration of the combustible materials in the neighbourhood.

All these facts concur to corroborate the conclusion, that pyrites is one of the principal causes why peat mosses kindle of their own accord. At all events, they may account for this very high degree of inflammability which that substance sometimes possesses. Especially when we know for certain that similar conflagrations take place in other substances, in themselves less inflammable than peat, from similar causes. To mention intances of this were superfluous. Those at Whitehaven, Puddle Wharf, Ealand in York, and Whitestable in Kent, are well known. That which occurred at Charmouth in Dorsetshire, deserves to be noticed. The cliffs consist of a dark-coloured bituminous loam, full of pyrites. In the year 1751, these spontaneously took fire, and burnt for years. If so, is it surprising that peat moss, a

more inflammable substance, and in a much more *moist state*, should, in some cases, kindle into conflagration in consequence of the pyrites it contains? And is it surprising, that the more moisture abounds in such mosses, the more inflammable they become?

It may be added, that we may, from what has been stated in the foregoing pages, even account for the inflammability of the subsoil of some mosses, though it consist of a tough tenacious clay. The oils, and gums, and resins, of the vegetable matter of the moss, being all rendered soluble in the manner described, must not only be diffused through the whole moss, especially the lowest strata, but even penetrate into the subsoil itself, whether that consist of sand or clay. That a bituminous matter should be found in both, is therefore not surprising. The pyrites, too, by its specific gravity, must be still more apt to sink into this subsoil. By the combination of all these ingredients, that subsoil must participate of the inflammability of the moss under which it lies. Hence all the clays which I have ever examined under moss are impregnated with sulphuric acid, and yield the sulphat of iron on combustion. Hence most of them are inflammable. Hence, too, the schistus which accompanies surturbrandt and coal, are often impregnated with bituminous matter, to the depth of three, four, and even seven feet, as at Messner. And hence pyrites has generally been discovered wherever bituminous matter exists, whether in the fluid form of naphtha, petroleum, &c. or in the

more solid and concrete form of coal, surturbrandt, or peat.

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4. In order to estimate fairly, and to obviate fully, the objection of the ingenious Doctor, other considerations might have been taken into the account.

Suffice it only to notice these :

1. When he speaks of any moss being more inflammable than the original vegetables of which it is composed, he obviously means dried peat. When newly dug from the pit, the most compact moss contains one-half of its weight and bulk of water, or what is soluble in water. When the liquid is squeezed out of it by compression, it loses half its weight and bulk. And till this liquid be either squeezed out, or the moss dried in the sun, it is not generally so highly inflammable as the Doctor insinuates. To compare, therefore, a piece of dried peat with the green growing vegetables of which it consists, is not fair. In order to appreciate correctly, the relative degree of inflammability of that matter in its recent vegetable state, and in its ultimate form of moss, it is requisite that both should be equally *dried*. A fir plank, cut into the form and size of peat, and dried in the sun, for the same time, would be as inflammable *in general* as pieces of moss formed of the same vegetable matter, in the same circumstances.

It is, however, by no means insinuated that no wood or other plants are found in moss *much more* inflammable than they were in their original state.

On the contrary, this is allowed, and endeavoured to be accounted for, in the preceding section.

2. Some mosses have certainly been formed by forests ruined by fire; and the lower strata of such, must, on this account, be very inflammable.

A green growing forest, even of fir, though it burn, is not entirely consumed; it is more properly charred. Part of that charr, especially of the smaller twigs, must be reduced to powder. That of the trunk and larger branches alone must retain their original organic form. But in whichever of these states this charr may have been deposited, it is certain that it must long resist any change*.

This is not all. While such a forest of fir was burning, the whole resin it contained would not be consumed by the flames. As in the process of charring wood, a great proportion of it would flow down from the tree in a melted state. Diffused as a liquid mass over the surface of the earth, where the parent tree stood, it must mingle with the leaves, and twigs, and small particles of charr, that lay incorporated in this mass of ruins. Combining together, this resin and charr would form of *itself*, and *immediately*, a substance more inflammable than the forest of fir, in its original state.

Hence the peat, described in the first essay as con-

* Of all substances, charred wood is one of the most incorruptible. The beams of the theatre at Herculaneum, which were charred by lava near 1700 years ago, have been discovered as fresh and entire as the day they were overwhelmed by the volcano.

sisting chiefly of chips of charred wood, compacted together, is of a jet black colour, of a very compact and glossy appearance; sometimes it breaks with a vitreous lustre, and, at all times, it is highly inflammable.

If a fir tree yield one-fifth of its weight of charr, and if some of that species yield one-fourth of their weight of resin, what an accumulation of inflammable matter must have been deposited by such a forest when thus overwhelmed by fire?

But these considerations are of small account in comparison of those already mentioned. Taking the whole combined, however, it is hoped that the objections against the vegetable origin of moss, on account of the high degree of inflammability it possesses, may be completely obviated. And that the hypothesis that all moss whatever, even the most inflammable, is originally composed of vegetable matter, is not so supereminently extravagant, nor so utterly inconsistent with analogy, as the ingenious Doctor supposed.

SECTION II.

ANTISEPTIC QUALITY OF MOSS.

THAT moss water, and even moss itself, is possessed of this quality, has been mentioned already in the

third Essay. To attempt an elaborate proof of this were superfluous. The following facts may satisfy the reader.

1. Vegetable matter, of all kinds, is found in the deepest mosses in a distinct organized state. Oak and fir trees, and other ligneous plants, may be found entire. The two first species are sometimes discovered so fresh and firm, that they are fit for economical purposes. Even aquatic plants, which are of a much less solid texture, are frequently found in an organized state. To specify instances of this is unnecessary, as they are innumerable. Even utensils of wood have been found equally well preserved, though deeply imbedded in moss. "In the year 1773, in a turf bog in Ireland, some wooden bowls, iron heads of arrows, two or three sacks full of nuts, and a coat of very ancient texture, were dug up fifteen feet below the surface."

2. The horns, hoofs and bones of animals, have been detected in moss in a state of perfect preservation. The horns of the stag, and especially of that species which Pliny denominates the Cervus Hippelaphus, have been discovered in moss. In the island of Lismore, one of these horns was discovered, evidently perforated by art. Dr Walker observes, that this species has been extinct in Scotland for 700 years. Dr Percy, Bishop of Dromore, says, "that the horns of an animal, of uncommon size, are found in the turf bogs of Ireland. One of these, from the root to the tip, measured seven feet one inch. And

the extent from tip to tip of the two horns, was fourteen feet four inches." Dr Walker was of opinion, "that this species belonged to an animal of the deer kind, which is not known at present to exist anywhere on the globe. That this animal was once a native of Ireland, and the elk of Scotland, is evident from their remains, which have been found in peat moss. That they have been preserved for ages unknown in this situation, is obvious from this, that the existence of these animals, in these two kingdoms, is not only beyond the verge of history, but even of tradition."

Nay, whole skeletons of animals, the existence of which in a living state is as remote, have been found deep in moss. Stralenberg relates, "that an entire skeleton of an incognitum was found in Siberia, near Lake Izana Osero; that it was thirty-six Russian ells long. So great was the distance of the opposite ribs, that a man, standing upright on the concavity of a rib, as the skeleton rested on its side, could not quite reach to the opposite one, even with the aid of a pretty long battle-axe, which he held in his hand. He, and thirty other men, were witnesses of the fact. Dr Misserchsmidt saw the bones of a whole skeleton, between Tourskoi and Kamtsko, on the banks of the river Tomber."

It is unnecessary to observe, that innumerable relics of this kind, of a very great size, are discovered in the marshes of North America. Especially in the salines of Wabash, Illinois and upper Louisiana.

"In the latter, it is said that over a space of 300 yards, there is a vast congeries of bones, belonging both to the human and animal species, mixed together promiscuously; some lying on the surface of the morass, others sticking up, and the greater part sunk deep below it."

3. Even the softer parts of animals are found in a high state of preservation, though sunk deep in moss. Whole bodies have been dug up, which had lain for years, nay, for ages, in a state of preservation. Dr Walker mentions, that two human bodies, which had been buried in moss for nine years, were found unconsumed at the expiration of that period. Their flesh was quite fresh, pitting a little when pressed by the finger. Their joints played freely, without the least stiffness. Their clothing was also firm and good. Part of it consisted of serge, which seemed none the worse. Some bodies were dug up in Ards moss in Ayrshire, which had lain for a much longer period, even since the persecution of the covenanters in the reign of Charles II.

There is reason to believe, that a human body may be preserved for ages innumerable, if buried deep in moss. For some have been discovered with the most distinct marks of remote antiquity. In June 1747, the body of a woman was found six feet deep in a peat moor, in the Isle of Axholm in Lincolnshire. The antique sandals on her feet, shewed that she had been buried there for many ages. Yet

her nails and hair were as fresh as any person's living. Her skin was soft, of a tawny colour. It stretched like a piece of doe leather, and was as strong. In a turbary, on the estate of the Earl of Moira, in Ireland, a human body was dug up, a foot deep in gravel, covered with eleven feet of moss. The body was completely clothed, and the garments seemed all to be made of *hair*. Before the use of wool was known in that country, the clothing of the inhabitants was made of hair. It would appear that this body had been buried at that early period. Yet it was fresh and unimpaired.

It is unnecessary to add, that the bodies of other animals have been found in a state of equal preservation in moss. In digging a pit for a well near Dulverton in Somersetshire, many pigs were found in various postures, still entire. Their shape was preserved. The hair remained on their skin, which had assumed a dry membranous appearance. Their whole substance was converted into a white, friable, laminated, inodorous, and tasteless substance. When exposed to heat, however, it emitted an odour precisely similar to broiled bacon.

But it is of importance to observe, that the above instances are sufficient to shew, that peat moss is possessed of a powerful antiseptic quality. For, if not only the vegetable matter of all kinds, but even all the parts of animals have been preserved, not for years, but for centuries, in an entire state in that substance,

it surely must possess some powerful antidote to putrefaction.

If, however, any person doubts of the fact, he may easily bring it to the test of experiment. If he take a joint of meat, and bury it five or six feet deep in moss, he will find that it will continue quite fresh, and free of putrefaction, for years. It will lose its flavour, and acquire an earthy taste. This experiment has been tried with success.

This quality, like the inflammability of peat, has been considered by some as utterly *unaccountable*, and altogether *irreconcilable* to the hypothesis that moss is composed of *vegetable matter*. Dr Anderson expresses himself to this effect in very decided terms. His words are;

"If peat owes its origin to decayed plants, we must allow that these plants are here found in a state of preservation very different from what takes place in any other situation. Now, this must be owing to some cause. What, then, I ask, is the cause of this extraordinary phenomenon? If it be said that it is owing to the juices that are imbibed from decaying wood, this will only be shifting the question. We should then ask, *What are the juices which issue from wood, which produce this effect? Have they ever been seen? Have the effect of them ever been, in any other case, experienced? No! No such juices are known to have any existence in nature.* We have, therefore, a right to say, that no such juices do exist till you can produce them."

The ingenious Doctor thus boldly throws down the gauntlet. It may seem presumptuous in me to take it up. Yet, without hesitation, it may be roundly asserted, that there are juices which issue from decaying wood, and the other vegetables of which moss is composed, which are known to possess this quality. These juices have been ascertained, and the effects of them have been, and may yet be experienced. And there are other ingredients in moss, and other circumstances connected with it, that may account for the antiseptic quality of that substance, even to the highest degree which it possesses. To point out these, and to ascertain the *causes* of this quality, shall now be my object.

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1. *First, a variety of acids issue from decaying wood and other vegetables.*

A few of these may be named:

The carbonic acid is supposed by *some* * to exist in all vegetables, even in a recent state, and it is allowed by all to abound when they begin to decay. That this operates as an antiseptic, both to vegetable and animal matter, is beyond a doubt. Of this there is little need of proof. A few facts and experiments may, however, establish this point, and set it in a clearer light.

* This opinion is now exploded. Though the carbonic acid is formed during the fermentation of dead vegetable matter, yet it is not found to exist in the vegetable in its recent growing state. But as all peat moss consists of dead vegetable matter, it is not improbable that this acid may have been formed in it.

It is certain, that water impregnated with this acid becomes harder. That is, it does not readily dissolve soap. It is equally certain, that it is less apt to become putrid, than water which contains little or none of this acid. Celsus discovered this many years ago: "Aqua dura est ea quæ tarde putrescit." And the acute and ingenious Dr Home established the fact, by the following simple, but satisfactory experiment. His words are: "I exposed four English pints of this hard water, in an earthen vessel, near the kitchen fire, on the 1st July. On the 14th, it was still sweet and hard. On the 24th, it was still the same. And it continued so, till it was thrown out, Nov. 11th, as incapable of corruption. By that time it was reduced to half the quantity. Instead, however, of being softer, it was *twice as hard* as at first. For it required twice the quantity of soft water, to make it break soap."

From other experiments of the same ingenious gentleman, it appears that this acid restores water which had become partly putrid, and renders it pure. "I put," says he "into the same quantity of the same water, on the 24th July, a large handful of dung, to hasten its putrefaction. The water acquired a corrupted smell for two or three days. After that, it became sweet and hard, and continued so till the 11th November, when it was thrown out."

Mr Howie has tried a similar experiment with water that had become putrid at sea. He poured

a quantity of carbonic acid into it, which rendered it pure.

Nay, animal matter may be preserved from putrefaction, by immersing it in water impregnated with this acid. Dr Home has tried the experiment. "An ounce and a half of beef was put into a glass, containing six ounces of soft water, on the 12th Nov. The same quantity of beef was put into another glass, containing the same quantity of hard water. The same was done with two other glasses, with the same quantity of fish. On the 22d of that month the fish and flesh in the soft water were putrid. In the hard they were quite sound. Hence," he adds, "we may observe that hard waters have a strong power of preserving animal matter. Waters, however, three times harder, must have a very strong antiseptic power."

From the first experiment, it appears, that carbonic acid preserves water from becoming putrid; and that, even though that water be partly evaporated, the antiseptic quality is increased in place of being diminished. From the second and third, it appears that it restores water, which has already become putrid. And from the last, that it preserves animal matter from undergoing that process.

Carbonic * acid, therefore, may be one of those

* Carbonic acid extinguishes fire. It may therefore be supposed, that if it abound in moss, that substance must cease to be inflammable; and that this account is inconsistent with what is stated in the foregoing section. To this it may be replied, that this acid being soluble in water,

juices which issue from *decaying* wood and other vegetables, which may account for the antiseptic quality of peat moss. For not only does it exist in this vegetable matter, but being soluble in water, and having a powerful affinity to that liquid, it may thus be diffused through every particle of the moss. That it is soluble in water there is no occasion to prove.

Gallic acid also exists in many, and abounds in some of the ligneous and aquatic plants of which moss is composed. In its composition it is similar to the carbonic acid. It is soluble also in water, and may be diffused through the whole mass of vegetable matter. It is also possessed of similar antiseptic powers. That it is held in solution, in many moss waters, is clear from this, that they effervesce with chalk, and form an inky precipitate with the sulphat or other salts of iron. That it is diffused through the water in which vegetables containing it are immersed, is equally clear. For when a quantity of leaves and boughs of oak are left in a wood, in any low spot, where water is allowed to stagnate, that water becomes brown, and then of an inky black colour.

is mostly expelled from the peat, in the process of drying it. The little that remains is expelled in the first stages of combustion. Hence Venel observes, "that peat is slow of kindling, and emits a smoke at *first*, which *extinguishes flame*. It is not till this is expelled, that peat burns with flame or fury, that is, when the hydrogen and other inflammable matter it contains is burning."

By this means, any moss which is chiefly composed of the rubbish and ruins of a forest of oak, must be highly impregnated with this acid. Of course, such a moss may be a more powerful antiseptic than one composed of birch, beech, or aquatic plants, which contain less of that acid.

By this means, too, those mosses which lie in low level grounds, in the vicinity of an oak forest, may become more and more antiseptic. The gallic acid of the leaves and twigs, and bark, being all soluble, must be washed down from the adjacent declivities of the wood, and lodging in the level moss, where it must stagnate, must occasion a continual accession. By this means, the water of such mosses may acquire additional doses of that acid, not one year only, but during the whole period that the forest exists, and the moss is forming.

That water is susceptible of double, treble, and quadruple doses, and may thus become more and more antiseptic, Dr Home has proved by experiment *.

If so, it is obvious that, in low level mosses, there

* That experiment was made with carbonic acid; but the same is the case with the gallic. "I made some lime-water," says he; "in half-an-hour after, I poured most of this *single* lime-water on fresh lime. About the same time after, I poured the *double* lime-water again on quick-lime, and so made a *triple* lime-water. Still on lime I poured this *triple* lime-water. An hour and a half after this, the single lime-water required nine spoonfuls, the double eleven, the triple thirteen, and the quadruple seventeen, before they would break soap."

may be an accession of these acids in such situations as have been described; partly by evaporation, by which the water that is left becomes more antiseptic, and partly by more carbonic and gallic acid being washed down from the adjacent forests or mosses which contain these acids. And if water, impregnated with them, operates as a powerful antiseptic, may not this be one reason why peat moss is possessed of that quality?

It is deemed necessary to take notice of this subject, as it has been insinuated by some ingenious men, that the antiseptic quality of peat cannot be ascribed to the vegetable acids it contains. Dr Walker is of opinion that they are inadequate to the purpose. He seems even to suppose, that it cannot be ascribed to the mineral acids, because they do not appear in our mosses so frequently, and so copiously, as to produce this general effect.

To this it may be replied, that though it is not generally the case, yet in some mosses, some of the mineral acids abound so much, that the antiseptic quality they possess may be partly ascribed to them.

The sulphuric acid exists in many, and abounds in some. In all those which contain pyrites or gypsum, this must have been the case. And the antiseptic quality of such mosses may be partly ascribed to this acid.

But besides these acids there are,

2. *Other substances which exist in moss, which may account for this quality.*

The carbonaceous matter that abounds in every moss, and the gums and resins that must have been deposited in some, if not in the greatest part, are of this description.

Charred wood certainly abounds in the lowest strata of some mosses. Especially those which have been originally formed by forests consumed by fire. This is a substance not only nearly incorruptible in itself, but it operates as a powerful antiseptic; it purifies water though already putrid. Deyeux's experiment is decisive on this point. He took foul water from a dog-kennel, and some in which putrid carcases had been immersed for three weeks. When this water was poured through a filter of charred wood, it run off perfectly pure and limpid, free of any taste or smell.

Charcoal removes the putrid smell from substances. Mr Van Gems and Mr Kels have established this by a variety of experiments. The latter by distilling ardent spirits (which had been used in preserving animal substances) in charcoal-powder, removed the fetid odour from them. And Mr Lowitz found, that a wooden vessel, tainted with the odour of empyreumatic oils, when rinsed with powdered charcoal, was robbed of the fetid smell. It has been found, too, that a barrel charred within will preserve meat fresh for months without any salt. May not

the charred wood that is found in some mosses, and the carbonaceous matter which abounds in all, be one cause of the antiseptic quality of that substance?

The extractive matter of most vegetables, and the resins of some which exist in moss, may be another cause of this quality. That the former is soluble in water, cannot be doubted. That the latter, by means of the chemical agents in moss, have become partly soluble, is equally obvious from what has been stated in Essay V. If so, the water in which they are dissolved must, on this account, become antiseptic. This will appear obvious from the following experiments of the ingenious Dr Home, so often quoted already. They exhibit, at one glance, a comparative view of the antiseptic qualities of different substances.

Dec. 1st, one ounce of beef was put into a glass, containing 8 oz. of soft water: Call this No. 1. The same was done in No. 2. with an addition of a scruple of common sea-salt. No. 3. contained the same, with two drams of the same salt. No. 4. the same with a scruple of the crystals of pure sea-salt. No. 5. with the addition of two drams of the same salt. No. 6. the same quantity of beef in the same quantity of hard water. No. 7. the same in fresh made lime-water. No. 8. the same in *tar water*.

Dec. 8th, No. 4, and 5, began to smell putrid, but the latter not so much as the former. No. 2. began to have a little smell, but not near so much as the two former. Dec. 16th, No. 1, and 3. began to smell. No. 2. very putrid. No. 7. is likewise

very putrid, but still so hard that it curdled soap. No. 6. quite fresh, with a quantity of air-bubbles on the surface of the water, which shews a beginning change. Dec. 26th, No. 6. smells putrid. No. 8. continues still sound.

From these experiments, it appears that hard water is a more powerful antiseptic than lime-water. And that *tar water* is much more powerful than any of the above. If so, is it not reasonable to expect that the gums and resins of plants, immersed in moss, by becoming partly soluble, must be diffused through that substance, and by this means communicate a powerful antiseptic quality to the whole? And may we not conclude that these also are some of the juices which issue from decaying wood, which may account for this quality? And, that the longer that wood lies immersed in water, the more of this resinous matter must be rendered soluble, and the more antiseptic such mosses must become?

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3. *There are new combinations formed in moss, which may account for this quality.*

According to the foregoing hypothesis, compound substances are formed in moss, which are powerful antiseptics. Whatever may be the changes and combinations by which bituminous matter is formed, and whether it be in the manner described in the foregoing essays or not, it is certain that every species of bitumen, from the purest naphtha to the coarsest mineral pitch, has been detected in peat moss; and it cannot be doubted, that in some mosses it abounds.

Must not all such mosses, on this account, be possessed of a high degree of this quality?

It is allowed by all, that bituminous matter operates as a powerful antiseptic, both to vegetable and animal substances; and that when the pores and tubes of either are impregnated with it, they may both be preserved for ages. It is even supposed by some, that bitumen forms the chief ingredient by which the ancient Egyptians, and other nations, preserved the bodies of their departed friends. Brongniart says, that the Egyptian mummies were preserved by asphalt, and a mixture of cedria, extracted from the cedar-tree; and that this liquor penetrates into every pore of the body, and enters even into the bones.

Whether this be the case or not, it is certain that the bituminous oils, extracted from moss by distillation, or found swimming on the surface of mossy lakes, operate as powerful antiseptics. Woodward observes, that the amber oil found in the waters of Hassel moss, preserves raw flesh like a mummy. And all the liquid bitumens found in moss operate in the same way.

That this may be one, if not the CHIEF cause of the antiseptic quality of peat, is accordingly the opinion of many distinguished men who have directed their attention to the subject. Mons. Thorin is of opinion, that the oil which is extracted from peat in the first stages of distillation is the cause why moss water does not become putrid, but preserves the vegetable matter, immersed in it, from putrefaction.

Mons. Macard supposes, that the bitumen discovered in the peat of Hanover, (which is the cause of its inflammability) is likewise the cause of its *embalming* quality. And Dr Walker is decidedly of the same opinion. His words are, wherever an acid is combined, either by nature or art, with the inflammable part of vegetables or animals, a substance of a bituminous nature is produced. The vitriolic ether, and such like combinations of inflammable matter with the mineral acids, can only be considered as so many artificial bitumens. Such a bituminous matter we find in peat. To this the antiseptic quality of moss and moss-water seems chiefly to be ascribed. It is well known that the natural bitumens are, in themselves, incorruptible; and that they are of great power in preserving all vegetable and animal bodies from corruption, The same, to a certain degree, is the case with peat. By means of the bitumen it contains, it is, in itself, not only preserved from the ultimate stages of putrefaction, but is rendered capable of preserving other bodies. This, so far as appears at present, is the most likely cause to which the antiseptic property of peat can be ascribed. It cannot be ascribed to the mineral acids; neither is it owing to the vegetable acid, which is still more feeble. But probably to a union of the vegetable acid with the inflammable matter of the vegetable substance, the result of which combination must be a bituminous matter.

Probably the *saline* substances discovered in peat

may be another cause of this quality. At least some salts discovered in that substance may co-operate to this effect. A few of these may be named.

Epsom salt has been discovered in some mosses. The sulphat of alumen is found in others. The sulphat of copper in some, and the sulphat of iron in most mosses. Yet all of these saline substances operate as antiseptics. The following experiments of Dr Home prove this. Five grains of Epsom salt hardened two spoonfuls of water so much, that it required to be diluted in sixteen spoonfuls before it began to break soap. Alum renders soft water very hard, so that five grains required twenty spoonfuls of soft water before it would break soap. Salt of steel hardens water. I was obliged to dilute ten grains in forty-five spoonfuls of soft water to make it break soap. Blue vitriol, or salt of copper, hardens water so much, that it required thirty-five spoonfuls of soft water to make five grains of this salt break soap. Five grains of salt of amber made water so hard, that I was obliged to dilute it in fifty spoonfuls before it would break soap.

Some of these salts exist in some mosses, others in others, and a few of them in all. Is it not therefore probable, or rather certain, that they contribute their part in promoting the antiseptic quality of moss and moss water?

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4. *There are other considerations* to be taken into the account, independent of the juices which

issue from decaying vegetables, and the combinations they form.

The situation in which these vegetables are placed, and the subsoil on which they lie, may contribute to communicate this quality to peat.

The situation in which they are placed may operate to this effect. Immersed in water, generally in a *low* temperature, and that temperature almost always *equable*, free from those *alternations* of moisture and drought, heat and cold, which so powerfully promote the putrid fermentation; in a word, secluded from those *chemical agents* which uniformly tend to accomplish that process, is it not obvious that it must be arrested? Where a superabundance of moisture, a low, and especially an equable temperature reigns, and still more, when there is no access to the atmosphere nor the oxygen it contains, and no alternations of heat and cold, it is impossible that the putrid fermentation can advance to its ultimate stages. Yet this is the precise situation in which nine-tenths of the mosses of Europe are placed. Any vegetable or animal body, placed in a similar situation, must be preserved for a long period from putrefaction. Perhaps that process, correctly speaking, could not be accomplished in such a situation. To this, therefore, the antiseptic quality of peat may partly be ascribed.

The subsoil on which mosses lie may be another cause. M. De Luc, in his letter to me of 12th December 1808, is of opinion, that it ought *chiefly* to

be ascribed to this. His words are, "We agree in one point, that an antiseptic quality in the water is the cause of that decay of vegetables by which peat is formed. But you look for the cause of that quality in the plants in the moss which you analyse on purpose. I consider it as depending on the *nature of the ground.* My reason is, that the same plants which are converted into peat in the moors, are putrefied in the marshes. If it did not depend on the nature of the ground, peat might be produced on every swampy spot, by sowing the seeds of plants which grow on peat moors. But that would be without effect. Let us come to a general definition of peat. It is a congeries of all sorts of vegetables collected in water, which, to the last degree of their decomposition, retain the combustible property. It is not, therefore, from the vegetables, that the water acquires this antiseptic quality, since they are not decomposed, it must be owing to the grounds on which that accumulation is formed." In a subsequent letter, April 1808, he makes the following observation: "Your account of ancient forests is particularly interesting. These forests have furnished materials for peat in many places. But they have not in themselves the *cause* of it. There must be *stagnant* water, and that water, by some AS YET UNKNOWN cause, must have an *antiseptic* quality."

The above remark is ingenious, and worthy of the celebrated author who makes it. And there can be no doubt that there is much truth in it. The

lime-water in some cases, the mineral acids in others, which issue from the subsoil of some mosses, may co-operate in communicating this antiseptic quality to that substance. The saline substances too, which are held in solution in the waters of the subsoil, may co-operate. Still it appears to me, that the subsoil, and all that proceeds from it, only *co-operate*. The *principal* sources from which this quality proceeds, must probably be traced to the vegetable matter of which the moss is composed, and the combinations which it forms. The vegetable acids and extract, the essential oils, and gums, and resins, which exist in that matter in its recent state, and the bituminous and saline substances formed in the more remote stages of decomposition, seem to be the chief agents, and the great causes of this peculiar quality. And when all these are taken into the account, they may occasion the highest degree of that quality which any moss possesses, *independent of the subsoil.*

If the skeleton of any large quadruped were found lying on the ground, so entire that we could easily ascertain the species to which it belonged; and if the spot on which it lay were covered with rich verdure, while the adjacent ground was barren, we would naturally conclude, that this animal had not only perished on the spot, but that this verdure was *owing to this cause more than the soil on which it lay*. In like manner, when we discover in moss the skeleton of trees, and of smaller vegetables, so entire that we can ascertain the distinct species to

which they belong; and if we are certain that most of those plants possess antiseptic juices; and if we find that all moss which is compounded of these materials, is possessed of the same quality; is it not equally reasonable to ascribe that quality more to the materials thus accumulated, than to the soil on which they lie? More especially, as this soil is not possessed of that quality, where it is not covered with these materials, though in the immediate vicinity.

SECTION III.

OF THE COLOUR OF MOSS AND MOSS-WATER.

THE water that issues from moss is generally of the colour of coffee. Sometimes, however, it is of a darker tinge. And some moss-water is of a deep *inky* colour. There is a similar variety in the colour of moss itself. In general, it is either of a dirty yellow, or marly brown, or red colour. Sometimes a tinge of green or blue may be discovered in it; and it is often jet black.

When dug and exposed to the air, it uniformly becomes of a darker colour. The yellow becomes brown, the brown becomes deeper, and, when thoroughly dried, quite black.

This colour of peat has been ascribed to various causes. Some have supposed that it is owing to the

putrid fermentation. Dr Walker seems to have been of this opinion. "The black colour of peat," says he, "is to be ascribed chiefly to the putrid fermentation. All vegetables turn to this colour when putrid; and the more perfect the putrefaction, the deeper the colour. The most ancient, and to appearance, the most *putrid* peat, is always the blackest. Like tanner's bark, though of a light brown colour when put into a stove, yet after being retained for some months in a high putrefactive *heat*, it is turned out quite black. Neither is it unlikely that the formation of bituminous matter in peat may tend to increase the black colour, as this colour is peculiarly prevalent in most bitumens, and often in the most intense degree."

The facts stated above cannot be doubted. The reasoning founded on them is plausible; and the general principles laid down cannot be controverted. It is doubful, however, whether this reasoning, and these general principles, are applicable to moss. For in general, few, if any mosses, have undergone the *putrid fermentation*. Few have been exposed, like the tanner's bark, to a high putrefactive *heat*; and in *none* that I have examined has this process been *completed*.

Professor Jameson gives the following ingenious account of the matter. He seems to ascribe the colour of peat to the *dissipation of hydrogen* and the *precipitation of carbon*. And he thinks that peat is vegetable matter, deprived of a considerable

portion of hydrogen. He illustrates this by the following interesting experiments :

"Sulphuric acid, when added slowly to oils, and triturated, they gradually become brown when the oil is rendered soluble in water and spirit of wine. But if acid be added in too great a quantity, a black insoluble matter is formed. If oleum animale be exposed to the action of oxygen gas, water is formed, and carbon precipitated. In the last experiment we observe, that the separation of hydrogen causes the precipitation of carbon. And in the experiment with the sulphuric acid, we observe, that in proportion as hydrogen is dissipated, the carbonaceous bases become more or less soluble in water; and when the whole hydrogen disappears, a true carbon is left behind.

"In the same manner, with regard to peat, the woody or vegetable matters are slowly deprived of their hydrogen; they become brown, and somewhat soluble in water and spirit of wine, thus forming a kind of bituminous matter. By farther decomposition, more hydrogen is separated, when the vegetable matter becomes insoluble in water, but still soluble in alkali. Lastly, the *whole hydrogen* is nearly separated, when a black substance is left behind, which we call *peat earth.*"

The facts are clearly and correctly stated. The theory founded on them is beautiful and simple; and the whole reasoning seems to be fair. It is founded, however, upon this supposition, that peat is

robbed nearly of the *whole hydrogen* of the recent vegetable, and that the more hydrogen is separated the formation of moss is more complete.

To this theory there is one insuperable objection: that no peat moss is robbed of nearly the whole hydrogen which the recent vegetable contained. On the contrary, bulk for bulk, and weight for weight, it in general contains more hydrogen, in the remote state of peat, than in its recent vegetable state. Nay, more, when the hydrogen is nearly all separated from peat, it literally becomes *peat earth*. In this state it differs little from vegetable mould, and possesses few of the distinguishing qualities of moss. It is scarcely *inflammable* at all. It may burn, but it will not emit the *bright flame* of peat. It is no longer a tough *tenacious mass*, but *friable* and *fertile* as mould. While this general remark is made, it may be added, that the professor's theory may be applicable to some species of moss; and it may be a correct account of their origin, formation, and colour. Such as have been formed of the ruins of a *burnt* forest, and such as have spontaneously *kindled and burnt with fury*, may be precisely in the state described above. And the colour of such mosses may be ascribed to the causes there assigned. The dissipation of hydrogen, and the absorption of oxygen, and of course, the precipitation of carbon, in all such cases, must be the consequence of combustion.

It is also true, that, in fermentation and distillation, as well as combustion, all this takes place. Hence

vegetables exposed to the external air, and the oxygen it contains, undergo all these changes, though *slowly*. The leaves of trees, when they begin to decay, turn yellow. After they drop, and are still longer exposed to the air, they become red. At last they appear perfectly black. The same, too, is the case with oils, and bituminous substances. Though of an amber colour when first exposed, they become speedily brown, and afterwards black. When any powerful acid is applied to any of these substances, as Mr Jameson justly observes, the same changes are effected, but in a more rapid degree.

In all of these processes, as in combustion, there is, indeed, a dissipation of hydrogen, an absorption of oxygen, and precipitation of carbon. And in all of them there is, of course, a progressive change of colour. In the first stages of all of these processes, the yellow becomes brown; afterwards it becomes darker and darker, till literally a true carbon is left behind.

In all such cases, therefore, where moss has been long exposed to the *external air*, or the oxygen it contains, or to the operation of such powerful acids, or other chemical agents, as to occasion the dissipation of hydrogen, and the absorption of oxygen, either by the slow process of oxygenation by the air, or the more rapid by the application of powerful acids, or the most rapid of all, by combustion; in all such cases, the theory above-mentioned may be correct. And such mosses, after such a process, will

be literally robbed of nearly the whole of their hydrogen. There will be, in all of them, a precipitation of carbon ; they will all be therefore black earth. But they will no longer be possessed of the distinguishing *qualities of peat moss.*

But *few* mosses have been exposed to such agents, or subjected to such a process. Perhaps not one in a hundred. The vegetable matter they contain has not been exposed to the oxygen of the atmosphere, for it is generally immersed in water, or covered with a mass of impervious moss. The sulphuric and other acids may have had access to this vegetable matter, even at the greatest depth; but though this acid may have combined with the essential oils of the vegetables, and though oxygen may thus have been absorbed, and carbon precipitated, yet the hydrogen has not escaped in a *gaseous* form, as it does in the processes of oxygenation, in the external air, or distillation, or combustion. On the contrary, though it has been set free, it has not escaped from the moss. But shut up as in a *close retort*, it has formed new combinations. Hence it is still found, perhaps in greater abundance, for reasons already stated, than it existed in the recent vegetable. Hence no peat whatever is nearly stripped of hydrogen.

But the dissipation of hydrogen, though it had taken place, or the precipitation of carbon, which has certainly been effected, will not account for the colour of *some peat.* That substance is not only blacker than common mould, which may be account-

ed for, as it contains more carbon, but some mosses *communicate* a jet black colour, to wool, wood, ivory, and other substances, which cannot be ascribed to the carbon they contain. Some moss-waters, without any mixture of adventitious matter, dye woollen, and even linen cloth, of this colour; even the mud at the bottom of them serves this purpose. The *mire-black*, as it has been called, of Lough Neagh, is used in that neighbourhood, and even exported to England as a black dye.

This is not the case with the richest mould, though it contain a great proportion of carbon. There must therefore be, in such mosses, some peculiar cause which communicates and impresses this colour. For neither the putrid fermentation, nor precipitation of carbon, can account for it. There are obviously *other* causes to which it may be ascribed. And these may account for all the gradation of colour, and all the various tinges which moss assumes.

1. *The gallic acid* may account for the dark black colour of moss. It not only exists in most of the ligneous, and many of the aquatic plants of which moss is composed, but the leaves, and bark, and core of them contain it. Wherever a mass of such vegetables, therefore, is immersed in stagnant water, it communicates a dark colour; and the different parts of the same plants yield different colours. Dr Watson ascertained this by the following simple experiment: "The sap infusion of these plants, which contain the gallic acid, occasioned only a small

change of colour. The bark, when rasped down, and placed in a solution of the sulphat of iron, yielded a brown; the core, in the same solution, instantly yielded one of the most vivid blues." Many of the ligneous plants, which are found in moss, have accordingly been used as dyes. The juice of the alder is used for dying wood, wool, and ivory. The bark dyes skins of a black colour. And the ingenious Palissey long ago observed, " that wherever this plant lies corrupting, it tinges the earth with the same colour." He is of opinion that stones are tinged by the same means. The bark has also been used for a similar purpose. It yields a clear yellow juice. When this is exposed to the air, it acquires a brownish tinge by the absorption of oxygen. With the sulphat of iron it forms ink, which is used for dying yarn. It is almost superfluous to add, that the oak serves a similar purpose; or that the finest ink is made by a similar combination, of the gallic acid it contains, with iron.

It may be proper, however, to observe, that many of the aquatic plants which flourish in moss, communicate a similar colour, and serve a similar purpose. The Iris lutea palustris is of this description. Ink may be made of the roots of this plant. When these are cut into thin slices, and boiled and diluted in water, the liquid acquires a deep tinge. If a piece of iron be placed in this solution, and rubbed with a stone, the whole becomes of a black colour. The Pentaphyllium palustre is similar to this, and possesses a

similar quality. Dr Rutty observes, that "he found it growing at Holywood, in the county of Dublin; that the roots of it were of a glossy shining black. When he poured hot water on these, they became of a deep purple colour."

As the gallic acid must have existed in most mosses, and as it is soluble in water, it is not possible to suppose that it should not be diffused through the whole. It is equally impossible to conceive, that it should not come in contact with the iron, which also exists in all moss. As this combination uniformly occasions a dark brown, or black tinge, is it not probable that this may be one cause of the colour of moss?

It is true, that when peat is first dug, it is not generally black; for the most part it is brown. And it only becomes black when exposed to the air and dried. But this is consistent with analogy, and precisely what might have been expected. Fishers nets are composed of vegetable matter. When these are steeped in oak bark, or any other, containing the gallic acid and tanin, they assume the same brown colour of peat newly dug. But after being exposed to the air, they, like peat, become darker and deeper in colour, and at last perfectly black. Even common ink, which is a combination of the gallic acid and iron, is not perfectly black till it be shaken and exposed to the air. This exposure makes the combination more intimate, and the colour of course becomes deeper. The longer it is exposed,

too, it becomes less soluble in water, which is precisely the case with peat. Giroud has made a number of experiments to shew that this is the case. When he squeezed the juice out of a piece of moss, he found that it uniformly became deeper in colour, and less soluble in water the longer it was exposed to the air. At last it appeared like claret, or the colour of port wine.

2. The sulphuric acid, by a similar combination with iron, may be another cause of the jet black colour of some mosses. Dr Walker seems to doubt this: The black colour of peat, he observes, has been ascribed to the vitriol of iron, mixed with oak, alder, and other styptic vegetables. He adds, this may possibly be the case sometimes, but the ashes of the blackest peat are often white, which could not probably be the case if the colour was derived from iron. To this it may be replied, that the ashes of black peat are seldom white. Though they appear so, when newly burnt, they acquire a yellow or reddish tinge by exposure to the air; and they are generally attracted by the magnet. Of the truth of this every person may satisfy himself. Probably nine-tenths of all the mosses in the world will be found to contain a portion of iron. Many, certainly, contain the sulphuric acid; and in such as contain a considerable portion of pyrites, this acid must abound. The colour of all such mosses is uniformly black. Generally they are soft and greasy when dug. When dried they are always of a jet black colour. And that

colour may probably be ascribed to the combinations of iron with the sulphuric acid.

Accordingly many ingenious authors have attributed the colour of moss to this cause. Dr Hans Sloane, (Phil. Tran. p. 302.) says, that the blackness of the oak found in mosses is, in his opinion, owing to the vitriolic juices soaked into it. That the particles of iron carried into these bogs, fasten on the tree and give it this colour. In the 27th volume of the same Transactions, it is ascribed to a similar cause. "I presume," says the author, "that there can be no doubt that the subterraneous wood, found along the banks of the Thames, receives its blackness from the vitriolic juices of the earth. I have tried the experiment. Alder wood, whether green or old, becomes black in a solution of copperas." Dr Rutty is decidedly of this opinion: "The cause why wood in moss is so black," says he, "is owing to the vitriolic acid combining with the bark of the trees." Mr Lochhead, in his MS. Essay (already quoted), says that ebony is nothing else than the wood of oak. This king of the forest is the most durable of all vegetables, when in life, and is equally durable after death. It becomes greater in density and weight, and as black and hard as ebony.

The various tinges and shades of colour in moss may probably be owing to similar combinations of acids and iron. Some are of a *fawn colour*. These are generally mixed with shells or calcareous matter. And this distinct shade may be owing to that mixture.

A simple experiment will make this appear probable. Take a small quantity of the blackest moss, when newly dug, and mix it, while wet, with a little lime. Squeeze the juice out of it, and drop the solution of the sulphat of iron into it; the liquid, in place of being black, will assume a dirty fawn colour. May not similar combinations have been formed in such mosses as contain calcareous earth? To these, probably, their peculiar colour may be ascribed.

Sometimes a *greenish*-coloured water may be seen issuing from some parts of moss. This may be owing to similar combinations. The gallic acid, when much diluted with water, occasions a precipitate of this colour with the sulphat of iron. In moss, this acid may be diluted to that degree as to occasion this colour. The carbonic acid, combined with the gallic, occasions a similar tinge with this salt. Hence a little lime-water, poured into ink, gives it a greenish tinge. May not the same combinations be formed in some parts of moss?

3. The bituminous matter, which exists in most mosses, may be another cause of the various colours they assume. The common coffee colour of moss water is most probably owing to this. For, when evaporated to dryness, it uniformly leaves a sediment, possessing similar qualities to bitumen. It is inflammable, and it becomes darker and darker in colour, and less soluble, the longer it is exposed to the air. To this, accordingly, the ingenious Dr Walker chiefly ascribes the colour of moss in general. But

the dark inky colour of some moss-water must be traced to other sources. For though bitumen were dissolved in water, it would not dye wood, wool, ivory, and far less linen, of a deep jet black colour, as some moss waters do*.

SECTION IV.

THE TENACITY OF PEAT MOSS.

THOUGH peat, when newly dug, is soft, and spongy, and pliable, yet after being exposed to the air and dried, it becomes a hard *tenacious* mass, insoluble in water. In this state it is somewhat elastic, and will bend before it break.

This is what is meant by *tenacity*. And it may be considered as a quality in peat which distinguishes it from every other congeries of vegetable matter. It is a quality not inherent in mould. Though it is sometimes composed of a similar congeries of vegetables, yet when cut into the form of peat, and exposed to the air and dried, it becomes friable, and

* More has been said of the colour of moss than may seem to be requisite. In a subsequent essay, it will be shewn that this is a subject of more importance than may appear at first sight. The waters of some mosses have been used for economical purposes. As a dye, they are found to be useful. And, in some countries, nothing else is used for dying wool, &c. &c.

readily crumbles into powder, which is not the case with peat. The former is pervious to water, even when dried, the latter is not. The former is in part soluble in water, the latter is not. The former, though dried into powder, may, by restoring the proportion of water which existed in it, be restored to its former state; the latter, though pounded down, cannot again be made to adhere together, or form a tough tenacious mass. The former absorbs water and retains it; the latter, when thoroughly dried, does not *.

This difference has been deemed by some altogether *inexplicable*. By others it is regarded as utterly *inconsistent* with the idea that all moss is a congeries of vegetable matter. Dr Anderson expresses himself to this purpose, in very decided language. He argues thus: "Nor need we stop here, if in search of arguments to refute this hypothesis; we need only to open our eyes, and we see plain proofs on every side. It is known to every person who ever was in a peat country, that, if a pit be dug in quick moss, so as not to reach the bottom, it immediately becomes a reservoir, capable of containing water like a well in

* This distinguishing difference may be ascertained by a simple experiment. Take a piece of mould and a piece of peat, equally dried, and place them half lengths in water. That liquid will filtrate to the very top of the mould, and rise as in a siphon. In the peat no such filtration takes place.—Or, take two flower-pots, and fill the one with garden mould dried, and the other with dried peat, in a powdered state, place them both an inch deep in water. In a few hours the water will rise to the surface of the mould. The peat, on the contrary, will remain dry on the surface.

a bed of clay. How *different* is this from the state of *decayed vegetables?* It is well known that a dunghill, and every other mass of rotten vegetables, instead of retaining water in a fluid state, like a bason, absorbs it almost instantly like a sieve. Once more, then, we ask whence comes this most striking *dissimilarity* between peat and decayed vegetables, if they are the *same* thing? Again, whence comes it that peat, when dried, becomes a hard *compact* body, instead of being a friable *incoherent* mass, as decayed vegetables invariably are?" He then reverts to his favourite hypothesis: "It is therefore impossible for any human being who spends but a thought on the subject, not to be satisfied that, to whatever cause we ascribe the origin of moss, it cannot be to the accumulation of *vegetables*, which have grown on its surface, now in a *state of decay*. That it must be produced by the gradual increment of a vegetable matter *still alive*, and in a growing state, and *nothing else*."

The facts on which his hypothesis is founded cannot be controverted. That peat moss is *impervious* to water, even when lying in its original state; that it repels it powerfully after being dried; that it becomes a tough tenacious mass; that, in all these respects it differs from any other mass of vegetable matter, is readily granted. Nay, it may be added, that after peat is thoroughly dried, it is one of the most insoluble substances, and the least liable to change or dissolution. The two following facts will shew this. "A piece of dried peat was put into the

boiler of a steam engine for three months. Yet, though exposed to a heat greater than boiling water, it remained unchanged. The only difference that it exhibited was, that the surface of it was covered over with a kind of powder of iron, which attracted the magnet*. The centre, and all but the very surface, was unchanged." The other fact is, that dried peat may remain for ages unchanged, when immersed in water, or in a moist situation. Degner takes notice of this. He observes that "the Dutch frequently lay the foundation of their houses with peat. And he asserts, that after the house has decayed through age, the peat is found as sound and entire as at first."

But though peat thus differs essentially from other vegetable matter, it by no means follows that these distinguishing qualities are either altogether *unaccountable*, or utterly *inconsistent* with the hypothesis that all moss is of vegetable origin. On the contrary, it appears that these qualities may be accounted for, and that they are quite consistent with that hypothesis.

It has been already shewn, that bituminous matter exists in all moss, and abounds in some. The following observations are offered to shew that this may be one cause of the tenacity and insolubility of peat;

* Kirwan observes, that bitumens have a strong affinity to carbonaceous matter. Much stronger than to argil. They may be separated from the latter by boiling water. But from the former they can scarcely be separated by the strongest heat in a close vessel. The above experiment shews that this is the case with dried peat.

and that because peat is impregnated with bitumen, therefore it differs, in all these respects, from a mass of the same vegetables which contains little or none.

1. There are found in moss some trees which are thoroughly bituminated. They are, however, much more insoluble in, and impervious to water, than recent trees of the same species. And they are much less liable to change. Like peat, they may lie for ages in water, or a moist situation, unchanged. Like it, too, they are impervious to water, and insoluble in that liquid. Yet none can deny that these trees are of vegetable origin, and few will doubt that the bituminous matter with which every pore of them is filled, is the principal cause of their tenacity and insolubility.

2. The more bitumen any peat contains, when newly dug, the more insoluble and impervious to water it becomes when thoroughly dried. Light, loose, flaw, peat, recently formed, imbibes water much more readily than the solid black peat. The former contains much less bituminous matter than the latter. And as all the bitumens repel water, and are impervious to, and insoluble in that liquid, is it not highly probable that they are the cause of these qualities in peat? Can it be doubted, that a piece of moss, like that which Du Hamel describes, containing one-third of its weight of bituminous matter, must be impervious to water, either in a moist or dry state.

3. Though a piece of dried peat is thus impervious to water, yet when it is distilled, and by that

means deprived of the whole, or the greatest part of the bitumen it contains, it becomes equally pervious as a similar mass of vegetables. This is a presumptive proof that bitumen is one cause of this quality.

4. Though dried peat is, like bitumen, insoluble in water, yet, like it also, it is soluble in alkali. The flaw peat, in a few hours, is robbed of all the bituminous matter it contains, by a strong solution of potass or soda. That solution speedily acquires the dark deep tinge of port wine. The vegetable matter of the peat is left a beautiful porous mass, like network. Even black and highly bituminated peat becomes soluble in alkaline solutions, though by slower degrees. These solutions are similar in colour and consistency to those of flaw peat. And what is remarkable, though evaporated to dryness, and even exposed to a red heat, the residuum is still soluble in water. When put into that liquid, in the state of a dry powder, it is speedily dissolved. In consequence of the combination of alkali with the oil, (which combination, it would appear, is not destroyed by heat) this residuum *deliquesces in air*, and becomes a soft, pulpy, saponaceous mass, though formerly dried in a crucible.

4. Pounded bitumens still retain their repellent powers to water. Though immersed in that liquid, they remain an insoluble powder, incapable of being knead and compacted together. But if a small quantity of liquid bitumen be poured upon this powder,

it immediately coalesces, and forms a compact bitumen. This is precisely the case with peat, when thoroughly dried. "Though pounded into powder," Dr Anderson observes, "and in that state immersed in water, it cannot, by this means, be restored to its original mucous appearance, adhering together so as to form a tenacious peat. But if this powder be mixed with a proportion of *living moss*, in a soft state, the whole will become tenacious as formerly, when immersed in water."

This is a strong presumptive proof, that the bituminous matter in moss is the cause of its tenacity. In the *living* moss, as Dr Anderson calls it, that bitumen is still partly soluble in water. It has not been oxygenated like that of the dried peat. Of course, being soluble, it may penetrate and pervade every pore of the powdered moss, and thus, operating as a cement, may render the whole as tenacious as formerly.

5. As peat, when robbed of its bitumen, ceases to be tenacious; so, when bitumen is again restored, it acquires that quality. A simple experiment will prove this. Take a quantity of distilled moss, which is loose and friable, and impregnate it with any of the liquid bitumens, or with the bituminous oil, extracted during distillation, and expose it to the air, it will again become a compact tenacious mass, insoluble in water, and impervious to that liquid. Or take a pound weight of new dug moss, and put it into a flower pot; pour into it an alkaline solution;

allowing it to filtrate slowly and repeatedly through the moss, the alkaline solution will rob it of the bituminous oil, and the moss will become friable and pervious to water. If, however, this moss be immersed into a quantity of water, squeezed out of another piece of moss, it will, when dried, become equally impervious, and insoluble, and tenacious, as in its original state. Can it then be doubted, in this case, that the bitumen is the cause of tenacity and insolubility.

6. This liquid, squeezed thus out of new dug peat, or extracted from it by distillation, possesses most of the distinguishing qualities of bituminous matter. When evaporated to dryness, it is inflammable. When exposed to the air, it becomes darker and deeper in colour, and less and less soluble in water. The same is the case with all the bitumens. When exposed to the air, the most liquid become darker in colour, more concrete, and less soluble. In this concrete state, bitumen exists in dried peat. And probably it is the chief cause of its insolubility and tenacity.

It seems to constitute the difference, too, between *living* and *dead moss*, as Dr Anderson calls them. For when moss is robbed of bitumen, it *dies*, according to his hypothesis; and when bitumen is restored, it *revives*, or again acquires the qualities of what he calls living moss: so that if his distinction be correct, bitumen is the very life and heart's-blood of moss.

It is not, however, insinuated, that bituminous matter is the *sole*, but only the *chief* cause of the insolubility and tenacity of peat. There are other combinations which may co-operate in communicating these qualities to that substance.

7. As the gallic acid and iron exist in many mosses, and abound in some, these, by combining, may form an insoluble compound. The gallat of iron certainly exists in some mosses, especially in those which dye wood, wool, or ivory, of a jet black colour. This compound, when exposed to the air and dried like peat, becomes, like it, a black, compact, tenacious, and insoluble mass. Mr Davy, in his admirable essay on tanning leather, makes the following remark: "When pure water, in successive portions, was made to act on oak bark, in powder, till all the soluble parts were taken up, the liquor last obtained did not operate on gelatine." This is a proof that it contained little or no tanin. "But with the sulphat of iron it produced a dense black."—A proof that it contained the gallic acid. "And when evaporated it furnished a brown matter, which was rendered partly insoluble in water, by the action of the atmosphere." As such compounds must exist in many peat mosses, may they not be one cause of their tenacity and insolubility when dried?

Tanin, too, forms insoluble compounds. In its recent state it is soluble. From the above experiment of Mr Davy, it would appear to be more so than the gallic acid. That it must have abounded in

most mosses, at their first formation in this state, cannot be doubted. But when held in solution, it must have formed compounds with metallic matter, especially with iron. And such compounds are insoluble. That it exists in this last state in almost every moss, may be proved by the following simple experiments: When any of the reagents are employed, which have a more powerful affinity to the metallic particles than the tanin, it is thereby set free. Hence all the mosses which I have ever examined by such tests, yield a copious precipitate. I have tried alkaline solutions of every species of moss, with these tests. With some it yields a greater, and with others a less proportion of precipitate. But all yield a considerable portion, and some *nearly* as much as a solution of oak bark, or even the gall of oaks. That this combination is one cause of the insolubility, tenacity, and impervious nature of peat, when dried, is therefore highly probable.

All these combinations exist in peat moss, but not in vegetable matter which has undergone the putrid fermentation, and been converted into mould. In the latter there is no bitumen, no gallat of iron, and no tanin, in this insoluble state. In the former, all these exist in every moss, and abound in some. And the high degree of insolubility and tenacity which these possess may, most probably, be ascribed to these causes. Every pore of the vegetable matter of which they consist being filled with these insoluble compounds, they must be, on that account, impervious to

water, even in their original state; and they must be insoluble in that liquid when thoroughly dried.

SECTION V.

THE ACIDITY OF PEAT.

THAT this is one distinguishing quality of peat moss is allowed by all. The smell of it, when newly dug, and the pungent acid odour it emits when burning, bespeak the presence of some acid. On distillation, this acidity is uniformly discovered in every species of that substance. It is not, however, so easy to detect the particular acid that prevails, even though the acidity of the moss be apparent and strong. Amid such a mass of heterogeneous matter, the particular acids that prevailed at one period may be so adulterated and changed, that none of them may now be detected in a pure and simple state. In those mosses, too, which abound in calcareous matter, these acids may be partly or altogether neutralized.

These observations may account for some of the phenomena that have appeared in the analysis of peat moss, viz. that though the acidity of all moss is apparent, it is not easy to discriminate the particular

acid that is the cause of this, and that different acids have been discovered in different mosses.

The ingenious Dr Walker observes, that the acid in peat, in some of its characters, resembles the sorreline, the gallic, and suberic. He seems to consider it as allied to the pyroligneous. This presumption is countenanced by the smell of this acid and that of burning peat. He thinks it probable, however, that it may be found to be a distinct acid, peculiar to peat; at any rate, he supposes it to be of vegetable origin.

If so, it may be the carbonic, the acetic, the gallic, or the suberic, or perhaps a combination of them all. Professor Jameson, in his excellent treatise on peat moss, seems to be of opinion, that the suberic is the most prevalent in some species of peat. That which he discovered in Arran, and analysed, seemed to him to contain it. He says, that it is not crystallizable, but obtained, by evaporation, in the form of crusts. It tastes slightly acid, and forms a compound with lime, barytes, and soda. It decomposes the acetite of lead; and forms, with the sulphat of copper, a copious brown-coloured precipitate, having a beautiful green supernatant liquor. With sulphat of iron it also forms a brown precipitate, but the supernatant liquor is colourless. With nitrate of copper it changes the solution to a beautiful green, without causing any precipitation. In this respect it differs from the oxalic acid, which forms a precipitate. It differs also in another respect, that, with a solution of sulphat of indigo, it forms a beautiful green; whereas

the oxalic produced no change of colour. From all these circumstances he concludes that this is the suberic.

Perhaps the gallic and sulphuric acids are the most prevalent in moss, and the chief causes of acidity. The water squeezed out of moss generally forms an inky precipitate with the sulphat and other salts of iron. The probability is, that the gallic acid prevails in such mosses. It has been accordingly discovered in such a powerful state as to act on test papers, prepared with litmus or violet.

The sulphuric acid is much more powerful. Where it prevails, it must be the chief cause of this quality. Many mosses in this neighbourhood, as well as those already described, owe their acidity chiefly to this. When infused into warm water, and allowed to remain for some time, and afterwards filtrated through brown paper, the liquor is often so strong as to make test-paper red. With the muriate of barytes it forms a copious precipitate, which shews that the sulphuric is the acid that prevails.

Whether moss be considered as a soil or manure, it is of importance to ascertain whether this acid prevails in it. And before any extensive plans of improvement be set on foot, it would be prudent to make a few simple experiments to ascertain the fact.

But though acidity be a quality in moss which distinguishes it from vegetable mould, formed of nearly the same materials, it is not peculiar to that substance. The clay subsoil, which commonly lies

under it, is possessed of the same quality, and generally contains the same acids. These clays are therefore not improperly called *sour*. They frequently abound in the sulphuric acid, and are, on this account, very sterile till this acidity be removed.

SECTION VI.

Another distinguishing quality of moss is, that no living animal exists in it.

It is difficult to express this quality in more explicit terms. To prevent mistake, it may be proper to observe, that it is not insinuated that moss water is in general an unwholesome beverage, either to man or beast. On the contrary, it is generally safe, and sometimes salubrious. In certain diseases, it is supposed by some to be medicinal. Far less is it asserted that the air of moss is unhealthy. On the contrary, it is uniformly more pure and salubrious than that of carses or low grounds in the same latitude, where no mosses exist.

Yet it appears to have been ascertained that no living animal exists in that substance. Dr Anderson expresses himself clearly and correctly on this point. He says, " that moss is totally destitute of animal existence. That he never saw, or heard another

person say, that he saw a living animal of any kind in *quick moss*. *In dead* moss, worms and other reptiles are to be found; and eels, when it is deposited as a sediment from water, shelter themselves in it as among other mud. But they never are found in quick peat moss, though its consistency be such as one would think would naturally invite them to penetrate it."

This fact has been noticed in every climate where peat moss exists. It appears, too, that insects avoid moss water. Though they are seen perpetually hovering over stagnant pools, or swimming on their surface, and though they deposit their eggs in such situations, they are never seen in pools of moss water, though in the immediate vicinity. And no species of fish do exist in liquid moss. Degner takes particular notice of this. He observes, " that the waters of the lakes and pools of Holland, which have been cleared of moss, are always of an unpleasant smell and flavour, and that *no fishes can live* in them. Yet after the moss has been entirely removed, and a *current of fresh water* has been permitted to pass through these pools, they become sweet, and are then plenished with fish. These are supplied from the canals and rivers adjacent. And so abundant are the fish in this case, that sometimes 100 families live by fishing on one such lake."

But in moss, however liquid, or moss water, if *stagnant* and *unmixed*, no living creature can be detect-

ed*. This fact surprises some, and seems to others utterly unaccountable. Mr Aiton thinks that this quality is not peculiar to moss, but common to other soils. He therefore asks, " when did ever any man see, or expect to see, either vegetables or living animals below the depth of the soil?" Certainly living animals may be detected much deeper in other soils than in moss. The following experiment may be made, to ascertain the fact. Take a cubic foot of mould from under the surface, and place it in a frying-pan on the fire; a vast variety of insects and worms will rise to the surface, to avoid the heat. Take the same quantity of moss from the same depth, no such insects or worms will be detected in it. This shews that moss differs, in this respect, from other soils. And there can be no doubt, that, when these soils are mixed with such a superabundance of water as to convert them into mud, fishes of different kinds may be found in these situations, though not in moss of similar consistency.

There must, therefore, be some quality in the moss, or moss waters, which is unfavourable for nourish-

* There are exceptions to this general statement. In lakes which abound in *copious springs* of *pure water*, fish may be found, though these lakes lie in the very *centre* of a moss. Or when there is a current of *river water* entering *into* or passing *through* such lakes, the same may be the case. But in neither of these situations can these be called *mossy* lakes. The water they contain is not moss water, *strictly so called*; but such a *mixture* of spring or river water as renders them sweet and salubrious.

ing animal life, if not fatal to it. The hypothesis, advanced in the foregoing essays, may probably account for this distinguishing quality.

For, 1. It has all along been supposed, that moss has not undergone the last stages of the putrid fermentation, but that it is vegetable matter, arrested in some of the primary stages of that process. Now, it is known, that though vegetable matter, immersed in water, undergoes certain changes, yet, in the early stages of fermentation, certain gases are generated and evolved which are hostile to animal life. This point has been clearly established, and these gases have been distinctly ascertained. The celebrated Abbé Rozier has made a variety of experiments with this view. He observes, that the odour of hemp, which contains a resinous gum, when breathed by any animal, brings on a vertigo, or species of intoxication *.

He found that this poisonous quality exists in the *gas* that it emits. And he adds, that it is chiefly in the *early stages of the putrid fermentation*, which it undergoes when *watering*, that this odour, and these gases, prove so fatal to animals. In proof of this, he mentions the following interesting experiment:

* Kæmpfer, in his Amœnitates Exoticæ, makes a similar remark. He says, that an infusion of the leaves occasions a giddiness when it is used by any animal. Dioscorides observed the same thing; and adds, that all brutes of course avoid to eat of hemp. They reject the leaves of it, even when fresh.

He put some fishes and a quantity of hemp into a pond at the same time. On the second and third day after this, the fishes were affected. They avoided, as much possible, the hemp, endeavouring to swim on the surface. They became quite giddy, and at last motionless. A few were removed, and placed in fresh water. These speedily recovered; those that remained expired.

This poisonous quality, however, is not equal during all the fermentative process. It seems to be peculiar to the primary stages of it. For he observes, that, on the sixth day, he put other fishes into this same pond. These were neither giddy nor affected. He therefore concludes, that, in general, it is chiefly in the early stages of fermentation that these noxious gases are fatal; that they are entirely dissipated when that process is accomplished. That after this, fishes suffer less, or none at all.

He farther observes, in proof of this, that the air emitted from the pond, the first and second day, was similar to atmospheric air; as it is that which adheres to the external parts of the plant: That on the *third day* a *gaseous acid* is evolved: That, when the fermentation becomes rapid, an *inflammable gas* is discharged, and that this is what proves deleterious to animal life.

These remarks are interesting. The above experiment seems applicable to peat moss, and probably may illustrate the cause why that substance is hostile to animal life. It is true that hemp seldom,

if *ever*, contributes to the formation of that substance. But if a similar experiment is made with chips of oak or fir, or the bark of these trees, or any of the aquatics of which moss is chiefly composed, the result will be similar, though not so rapid. And such an experiment may appear more satisfactory, as being more synonymous to moss.

If, therefore, that substance be vegetable matter arrested in the primary stages of the putrid fermentation; if the acid of these vegetables, and the inflammable air contained in them, be not evolved in a gaseous form, (as has been uniformly maintained in the preceding essays), we may thus account for this peculiar quality of peat moss.

The *acid*, evolved from the hemp on the third day, is doubtless a *vegetable* acid. The inflammable *air*, evolved after, is no doubt hydrogen, or carburetted hydrogen. When these are both expelled, the water of the hemp becomes less fatal. But for the same reason, the air being impregnated with these deleterious gases, becomes proportionably less healthful. Hence Rozier observes, that an epidemic distemper raged in Paris, occasioned by the air of the stagnant pools in which the hemp had been watered.

Now, according to the hypothesis hitherto advanced, neither the acid of the vegetable matter of which moss consists, nor the hydrogen or inflammable air it contains, are expelled in a gaseous form. The fermentative process in that matter has not arrived at this stage. A sufficient degree of heat has not been ap-

plied. The air of all mosses, therefore, as might have been expected, is uniformly salubrious. And, on the same account, moss itself, and even the *water* contained in it, when *stagnant* and *unmixed*, proves fatal to animals.

If this hypothesis be well-founded, we may conclude that the

Vegetable acids in moss are probably *one cause* why it is fatal to animal life. The carbonic acid which existed in the vegetable matter, or which has been formed in the first stages of fermentation, may be one cause. It is certainly deleterious to fishes. Mr J. Hunter has shewn that they cannot exist many minutes in it. And it is probable, that this is the reason why quick-lime, thrown into a pond, kills the fish it contains. The gallic acid is equally deleterious. Hence any plant, containing a considerable proportion of it, when immersed in water, renders it noxious to fish.

The *hydrogen*, too, contained in the vegetable matter of moss, may be another cause why it is deleterious to animals. A proportion of oxygen in water seems to be as necessary for supporting living creatures in that element as in atmospheric air. It appears, too, that the water in the one case, as the air in the other, is decomposed during respiration. In both cases, oxygen seems to be absorbed into the animal system, while hydrogen is discharged. Hence Dr Priestley found, that the water in which fishes had breathed for some time, was robbed of part of

the oxygen it contained, while hydrogen was generated. And as an animal cannot exist long under a receiver which is air-tight, so neither can a fish exist long in water, (its natural element) if placed under the same receiver. The reason in both cases is the same. The oxygen of the air, in the one case, and of the water in the other, is speedily exhausted. Hydrogen is generated in both elements; and this gas is as deleterious to fishes in water, as it is to animals in air *. Without a constant fresh supply of oxygen, neither can exist. Dr Franklin says, that he was affected by an ague, by the respiration of hydrogen; and others have found that it occasions all the symptoms of an incipient fever, when inhaled. In hydrogen gas, neither insects, nor fishes, nor animals of any kind, can live; and in water impregnated with this deleterious gas, they speedily become giddy, and expire. Even worms and slugs cannot live many minutes in *earth* impregnated with it. If, then, moss be, as has been uniformly maintained, vegetable matter, from which the hydrogen has not been expelled in a gaseous form; and if moss waters be impregnated with a considerable and increasing pro-

* From the late experiments of Provencal and Humboldt, it appears that fishes require less oxygen than warm-blooded animals. A tench consumes, at an average, fifty times less oxygen than a man.

Yet, from the same experiments, (quoted in that excellent journal, Edinburgh Review No. XXX. p. 419, &c.) it appears, that even a tench, confined in water charged with carbonic acid, expires in a few minutes. The effects of hydrogen gas are found to be almost equally deleterious.

portion of this gas, it is nowise surprising that no animal can exist in the former, and no fish in the latter. It is, on the contrary, what might have been expected *a priori*. The proportion of this gas, discharged during the distillation of peat, or moss water, is so considerable in *all* cases, and so great in *some*, as of itself to be sufficient cause why no living creature can exist in either.

2. There are *combinations* of hydrogen in moss, equally deleterious to living animals. With carbon it forms carburetted, and with sulphur, sulphureted hydrogen. The former abounds in all moss, and is evolved during the distillation of that substance; the latter exists in many, and the water which issues from them is often highly impregnated with it. Both of these gases are deleterious to living animals. Dr Beddoes and Mr Davy have both made experiments with carburetted hydrogen. They found, that four or five inspirations of this gas immediately destroys life. When any fish is placed in water impregnated with sulphureted hydrogen, it instantly expires.

It is true, that carburetted hydrogen seldom escapes from moss while in its natural state; but for this very reason, it abounds the more in that substance, and is the more deleterious; for in whatever shape it appears, whether in a gaseous, or liquid, or solid state; *i. e.* whether as naphtha, petroleum, or in the form of peat, surturbrandt, or coal, it is hostile to animal life. No living creature is therefore found in

bituminous lakes. Relandus * takes particular notice of this. Even the air of such lakes is often so pestilential, that birds flying over them expire. The powder of surturbrandt destroys insects. Dr Uno Von Troil says, that the Icelanders make use of it for this purpose. The ampelite, which is an impure argillaceous bitumen, serves the same purpose. Coal-tar, mixed with water, kills worms, grubs, and other insects. Even the recent juices of some trees serve the same purpose. Tar water, for instance, is used in France for destroying insects on olive and fruit trees.

There can be little doubt, that it is the carburetted hydrogen which exists in *all* these substances, that is the cause of this; and there seems to be equal reason to conclude, that it is one cause why peat moss is so unfavourable to animal life: for, if this gas be so deleterious, and if some mosses yield one-third of their weight of bituminous matter, is it possible to conceive, that any living animal could exist in such a substance?

3. The *mineral acids*, and the *salts* they form in moss, may be another cause of this quality. The sulphuric acid is of this description. A very small proportion of it, diluted in water, renders that liquid deleterious. The combinations of this acid with metallic substances are equally fatal. A single drop of the sulphat of iron, or copper, even in a consi-

* In his Palestina Illustrata.

derable quantity of water, will render it poisonous. Broussonet mentions, that he tried the experiment with a large strong fish, and that it expired in a few seconds.

As this acid abounds in many mosses, and these salts in some, for this reason, all such mosses must be deleterious to living creatures. In such a moss as Du Hamel describes, (as containing half a pound of copperas in three pound weight of peat) no animal could possibly exist; and that which Dr Black analysed, and found to contain 2 oz. of copperas to the pound weight of peat, must have been equally fatal to animal life.

4. Perhaps the volatile alkali, which exists in moss, may be another cause of this quality. This gas is unfit for respiration; no animal can breathe in it without suffocation.

Thus, it would appear that the vegetable acids and hydrogen, which abound in all mosses, and the mineral acids, which exist in some, and the combinations formed by these substances are sufficient to account for this distinguishing quality.

And if the same proportion of these existed in mould, or any vegetable matter, it must on that account be equally deleterious.

The general conclusion, from the foregoing Sections, is, that none of the distinguishing qualities of peat moss are inconsistent with the hypothesis, that it is of vegetable origin. On the contrary, it appears, that all of these qualities may be accounted

for on that hypothesis. The *sterility* of moss is a quality of much more importance than any one of those that have been mentioned; and to some it may appear to militate more powerfully against that hypothesis, than any one, or all of the rest. Whether we consider moss as a *soil*, or *manure*, or a subject of investigation to the natural historian, this distinguishing quality claims particular attention. To endeavour to account for it, shall be my object in the following Essay.

ESSAY VIII.

ESSAY VIII.

ON

THE STERILITY

OF

PEAT MOSS,

AND THE CAUSES OF IT.

Moss, in its natural state, is almost entirely barren. No grain of any kind can be reared on it as a soil. And few grasses, fit for the use of cattle, grow on it. Though entirely composed of vegetable matter, and though that matter, when it has undergone the putrid fermentation, forms one of the richest of all soils, and an excellent manure, yet, while it remains in the state of moss, and possesses all the distinguishing qualities of that substance, it is unfit for either of these important purposes.

Dr Anderson expresses himself clearly on this point. He says, that it is ascertained that *living* moss can subsist few or no vegetables. That he never saw a single plant, that drew its nourishment from *quick* moss; though he does not assert that there are none that drew nourishment from it.

A few ligneous plants, such as the alder and birch,

and some species of firs, may exist on such a soil. And a number of aquatics flourish on it, and grow with a rapidity scarcely equalled by any plant in any other soil. But of *useful* roots, grasses, or grain, it produces almost none. Nor is it capable of producing them, till it undergo certain changes, which shall be described in a subsequent essay.

This distinguishing quality must have been very soon discovered. Degner observes, accordingly, that the very *name* of that substance in all languages, and all ages, signifies *sterility*. The German word *torff*, the Dutch *dorveen* or *dorfen*, the Anglo-Saxon *thorff* or *thurfe*, the Swedish *tarf*, and the English *turf*, all signify poverty and sterility. This shews, that in all these countries, and at the earliest periods of their history, this quality was so well known, as to occasion an appropriate name to be given to the substance. And the conviction of its absolute sterility is so deeply rivetted in the minds of nine-tenths of mankind, that every attempt to convert it into a soil is regarded as foolish, and given up as a forlorn hope.

Of all other qualities, this is by far of the greatest importance, and claims the most particular attention of the natural historian. To ascertain the *causes* of it must be his great aim. And till this be done, it is vain to attempt to remedy the evil. Experiments may indeed be made. But they are only made at random. In *some* cases they may succeed, with

some mosses. But that success can never be considered as a precedent in *all* cases.

The skilful physician probes the wound, examines every symptom of the disease, and traces it to its source before he prescribes the remedy. Even then he watches over the patient with solicitude, marks with careful eye the progress of the cure, and the principles on which it is accomplished.

If ever moss be reclaimed, and rendered capable of producing useful plants, it must be by following the same method. Without this, prescriptions may be administered, and remedies applied; but unless the disease be *first* ascertained, they may fail of success. For as there is no *plaster for all sores,* in the art of medicine, so there is no *one general* prescription, that will apply to every species of peat moss. And he who attempts to prescribe *one remedy to all,* acts the part of an ignorant quack.

That man who discovers the latent *causes* of the sterility of *all* moss in general, and of each species in *particular,* will deserve well of his country, perhaps of all Europe. The remedy will then be obvious, and the successful application of it in every case certain. The author entertains no sanguine hopes that he shall succeed in this very arduous task. But he rests confident, that the time is not far distant when such a discovery will be made; that he may throw in his mite, the following hints are submitted.

Of the Causes of the Sterility of Moss.

It is obvious, from what has been stated, that the

vegetable matter of which moss is composed, has not been exposed to the influences of the atmosphere; on this account it differs from mould, though formed of the same materials. On this account also, it is possessed of the distinguishing qualities already mentioned. It is more inflammable, more antiseptic, more tenacious, and contains more acidity than mould. On this account also it is more sterile.

SECTION I.

The *situations* and *circumstances* in which moss is *formed*, may be *one* cause of its sterility.

If the best garden mould were placed in the same situation, it would become equally sterile. If it were immersed in water, possessed of the antiseptic qualities above-described, and kept for ages in a low and nearly equable temperature, it would lose its fertility as a soil. And though turned up again, and exposed to the influences of the atmosphere, it would still remain sterile, till mellowed by the sun and air.

On the contrary, the most barren subsoil will become fertile when exposed to the atmosphere, and frequently turned up to its influence. A sod-wall, formed of a stiff *sterile* clay, or *barren* heathy soil, in the course of years, undergoes such a change in its texture and chemical qualities, that it becomes

fertile as a soil. The blaize or schistus of coal pits, by long exposure to the air, crumbles down into powder, and operates as a manure. Though, when first turned up, it is not only sterile, but destructive to vegetation; yet, after it has undergone these changes, it will cause a rich verdure over the soils on which it is spread. Even lava, when long exposed to the atmosphere, becomes a fertile soil. The surface of Sicily consists of mould formed of this; and it is highly fertile. The benificent Creator of all, has wisely ordained, that vegetable matter, decaying on the surface of the earth, should undergo such changes as to furnish food and nourishment to succeeding generations of similar vegetables; whereas, the same matter immersed in water, or buried deep in the earth, where it could not avail as a soil, undergoes different changes, and yields products fit for other purposes no less beneficial for his creatures. In the one case, food is provided for vegetables, and in the other, fuel for the use of man.

If the richest mould is robbed of its fertility, by being buried deep in the earth, may not this be one cause why the vegetable matter, of which moss is composed, becomes sterile? And if the most sterile soil, by being frequently turned up to the air, become fruitful: is it not reasonable to suppose, that moss may be stripped of its sterility by the same means? And has not the surface of most mosses partly undergone these changes?

SECTION II.

If peat moss be vegetable matter, which has not undergone the *putrid* fermentation, may not this be another cause of its sterility?

According to the hypothesis uniformly suggested in these essays, it is vegetable matter, arrested in some of the primary stages of fermentation. Secluded from the atmosphere, overcharged with moisture, and placed in a low and nearly equable temperature, that process cannot be accomplished. Of course, the vegetable matter, of which moss is composed, cannot undergo the changes requisite to convert it into a fertile soil. Senebier justly observes, that whatever retards fermentation, is equally unfavourable to germination and vegetation. And Lord Meadowbank, who has deserved so well of his country, says, with equal justice, "that the earlier changes, and in general, those which take place previous to the destruction of the texture of dead vegetables, yield *vapours*, which, when applied in a large proportion, appear to be rather pernicious than favourable to the growth of living vegetables, exposed to the direct effect of them; whereas, the changes subsequent to the destruction of the vegetable texture, promote powerfully the growth of plants."

If moss, therefore, be vegetable matter arrested in the early stages of the fermentative process, and vege-

table mould the same matter in which that process is accomplished, may not this be one reason why the latter is so fertile, and the former so sterile? His Lordship, however, has not mentioned what are the *vapours* which are pernicious to the growth of living vegetables in this case.

To elucidate this point the following hints are subjoined. Senebier has shewn, by experiment, that no grain will germinate in pears or apples, when they are nearly rotten. And it is known, that when certain trees are suffered to decay, on the surface of the richest soil, the juices that exude from them render it sterile for a considerable time. Abbé Rozier observes, that wherever a peach tree is permitted to perish, it vitiates the soil. And before another be planted in its place, it is necessary to renew the earth, to the depth of three or four feet. It is equally certain, that the liquor taken from a tan-pit, or the juice of any tree which contains the gallic acid and tanin, is equally hostile to vegetation.

May not the sterility of moss, in its natural state, be ascribed to similar causes? May not the carbonic and the gallic acid, which abounds in that substance, and the tanin it contains, be equally pernicious to the growth of living vegetables, as the juice of the apple, the oak, or the peach tree, or of the tan-pit above-named? Are not all these powerful antiseptics? And are they not equally unfavourable to *germination* and *vegetation* as to the putrid fermentation? Are they not all soluble in water, and may they not

thus be diffused through every pore of the vegetable matter of which moss is composed? And is not this one of the features which distinguish moss from vegetable mould; that the latter contains a very small proportion of these soluble ingredients, and the former abounds with them?

During the fermentation of vegetable matter they may be detected in it. But when that process is accomplished, the carbonic and gallic acids, and tanin of the recent vegetable matter, disappear. While they remain, they operate as antiseptics, and are therefore unfavourable to vegetation. After they are expelled, the vegetable matter is more susceptible of putrid fermentation, and therefore more fertile as a soil. This seems to constitute one difference between moss and mould.

Accordingly, the water which issues from the former, unless much diluted, destroys succulent herbs. An instance of this happened in this neighbourhood. The water that oozed from the moss, was permitted to overrun part of an adjacent field, which had been reclaimed, and sown down with grass seeds. The soil was a stiff tenacious clay. The hay was tolerable over all the field, excepting that part over which the moss-water flowed. There it was quite blighted, and it remains still in that state, after the lapse of months. This moss-water effervesces with chalk, yields an inky precipitate with the sulphat of iron, and with the muriat of tin it also affords a copious precipitate, like that of the gall of oaks, with

the same test. Is it not probable, therefore, that this water is possessed of similar juices with the trees, or tanner's bark, above-mentioned? And is it not equally probable, that the gallic acid and tanin are the causes of its being pernicious to living vegetables?

SECTION III.

THERE are certain *gases* detected in moss, which may be *another* cause of its sterility. A few of these may be mentioned.

Hydrogen, for the reasons assigned already, abounds more in moss than in vegetable mould, though composed of the same materials. It is known that this gas is pernicious to living vegetables, at least in its simple state, or when it abounds too much. Senebier has shewn, by experiments, that no grain will germinate in it.

Carburetted hydrogen is equally hostile to vegetation.

Sulphureted hydrogen is also deleterious. All these gases are entirely discharged from vegetable matter, when it has passed through the last stages of the putrid fermentation. It is otherwise in moss: in it they may remain. May not they contribute to the sterility of that substance? And may not these be the

vapours which Lord Meadowbank *justly* observes are pernicious to the growth of living vegetables?

SECTION IV.

All the varieties of *bituminous* matter have been found in moss, and may be another cause of this quality.

In whatever shape it appears, whether in its nascent state, as that discovered in the Bovey coal, or fully formed, as it appears to be in naphtha and petroleum, bitumen is hostile to vegetation. And as tar water is one of the most powerful antiseptics, it is more than probable that the gums and resins of vegetable matter in moss, even before they are converted into bitumen, are equally pernicious to living vegetables. For, in every case where the putrid fermentation is accomplished, these gums and resins disappear.

In whichever form they are found in moss, therefore, whether in their recent state, as gums and resins, or the more remote of resina-asphalt, or their ultimate form of naphtha, petroleum, &c. &c. in all of these stages they operate as powerful antiseptics, and are therefore hostile to vegetation. They pro-

bably operate, both mechanically and chemically, to this effect. Mechanically, as the coagulum or cement, which binds together the whole vegetable matter of which moss consists, rendering it a *tenacious*, *insoluble*, *impervious* mass, unfit for a soil. Chemically, by the vast proportion of hydrogen they contain.

If any one general cause of the sterility of moss were to be assigned, it seems to be the bitumen it contains. As an evidence of this, the following facts may be stated as the result of many experiments.

1. The more bituminous matter any moss contains, it is uniformly the more sterile. Hence Dr Leigh observes, no plant nor tree grows on Hassel moss.

2. When moss is distilled, and thereby robbed of the bituminous oil it contains, without any other change, it becomes a soil, fit for rearing vegetables.

3. When any quantity of moss is subjected to the putrid fermentation, not only the gums and resins, but all the bituminous matter it contained, disappears. The mechanical texture of that substance is totally changed. It is no longer a tough tenacious impervious mass, but loose and friable as mould. Its chemical qualities, as a soil, are also changed. It ceases to be sterile and becomes fruitful.

4. When a solution of potass or soda is poured into soft new dug moss, it becomes a pulpy saponaceous mass, almost entirely soluble in water. And it never afterwards can be formed into a tenacious peat. The alkali unites with the bituminous oil.

By rendering it soluble in water, the sterility of the moss is removed, and the whole is reduced to a fertile soil or manure.

5. Though dried peat be one of the most insoluble and incorruptible substances known, it may be dissolved in a strong alkaline solution. By this means, the bituminous oil uniting with the alkali to form an earthy soap, becomes of itself a manure.

6. It is almost unnecessary to remind the reader, that all the varieties of bituminous matter are hostile to vegetation; and that bituminous lakes and mud volcanoes, are uniformly barren, in whatever latitude or climate they may be found.

Are not all these strong presumptive evidences that the *bituminous oil* in peat is one great cause of the sterility of that substance?

SECTION V.

THE *mineral acids* in *some* peat mosses may be another cause of their sterility.

Such as abound with sulphur, and the acid it forms, may owe their sterility to this cause. That sulphuric acid abounds in some mosses, has been shewn already. That it is hostile to vegetation cannot be doubted.

Ingenhouz has proved this by experiments. When corn was planted in earth mixed with the flowers of sulphur, it flourished. But when oxygen entered into the combination, and formed sulphuric acid, the corn withered. Mr Nasmith's experiments corroborate those of Ingenhouz. " I poured" says he, " sulphuric and nitric acid, diluted in six times their bulk of water, into the bottom of two drills in garden mould. In these I sowed cress seeds, and also in an intermediate drill, without any acid. The plants appeared above ground two days later in the acidified drills than in the other. They were likewise much fewer in number and of a weakly yellow colour. The sulphuric acid seemed to be more injurious than the nitric." He adds,

" I also weighed an exact dram of the sulphuric, nitric, and muriatic acids, each of which I put into a pretty large tea cupful of water. I filled a fourth cup with plain water, and put two sound beans into each cup, where they steeped for forty-eight hours. Each pair of beans was then put into a separate flower-pot, filled with garden mould, and the liquor in which each had been steeped poured on the respective flower-pots in which they were planted. The beans in the sulphuric *acid did not germinate* ; and one of those in the nitric also failed. I opened and examined both. Those in the sulphuric acid were discoloured, and their *texture was destroyed*. The germ in that of the nitric acid was wasted, but the texture of the lobes was not much altered."

If the sulphuric acid, when mixed with mould in so *small* a proportion, renders it *sterile*, and if that acid abounds so much in *some mosses*, may it not be one of the chief causes of their sterility?

SECTION VI.

Some of the *salts* detected in moss may be another cause of this quality.

The sulphat of iron, in *small* proportions, operates as a powerful manure on *some* soils. But when it abounds, it is utterly destructive to vegetation. Of this every one may be convinced, by looking at the surface of the earth, where the water of coal and iron-stone mines is permitted to run. Being frequently impregnated with this salt, every vegetable substance is blighted and burnt up over which that water runs. The whole surface becomes red and barren.

But the following experiment of the ingenious Dr Home will shew what a *small* proportion of this salt may cause sterility to any soil. "I took," says he, "one pound weight of good mould, and mixed it with one dram of the salt of steel, and put it into a flower-pot. In this pot I sowed barley in the beginning of May. Some of the seeds sprung. But they were

ill-coloured and sickly, and then died. Whereas, the same number of seeds, in a pot of the same size, and containing the same quantity of mould, without this salt, throve well. Thus a very small quantity of iron, dissolved in the vitriolic (now called sulphuric) acid, rendered a quantity of earth, which was naturally rich, utterly unfruitful."

The vegetable poison in this case is obvious. And if one dram of the sulphat of iron be sufficient to render a whole pound of the finest mould utterly unproductive, how *absolutely sterile* must such a moss be, which Du Hamel and Dr Black describe, as containing one third of their weight of the same salt? No plant could possibly germinate on such a substance. And though there were no other cause of sterility, but this single salt, though the rest of the moss consisted of the most fertile mould, it is obvious that it must be rendered utterly barren by such a vast proportion of so deleterious an ingredient. But when it is considered farther, that this same peat contained one-third also of its weight of *bituminous oil*, besides a vast proportion of *hydrogen* and *carburetted* hydrogen, which escaped in a gaseous form when it was distilled, is it surprising that a substance, containing so many vegetable poisons in such abundance, should be *absolutely sterile?* And can we be at any loss in *this case* to ascertain the *causes* of that sterility?

That the sulphat of iron is one cause of sterility in such mosses as spontaneously take fire, is certain.

After combustion the whole surface remains a black blasted barren waste, without one vestige of vegetation*.

SECTION VII.

The *mechanical structure* of moss, as a soil, may be one cause of its being unproductive.

It is so impervious to water, and so tenacious in its natural state, and so loose, so porous and light, after being reduced to a soil, and so destitute of that mixture of different earths which enter into the composition of other soils, that some, if not by far the greater part of writers on the subject, have ascribed its sterility to this cause.

Mr Nasmith, in his excellent treatise, expresses himself to this effect: "The natural incapacity of peat to produce esculent vegetables, results from the peculiarities of which we have been treating. It is

* It is surprising and unaccountable, that, in no one case known to me, has any attempt been made to extract vitriol from such burnt mosses. There can be no doubt, that much of this valuble article might be extracted from some mosses of this description. A surface of five, ten, or more miles square, has been thus frequently suffered to retain this hidden treasure, to the utter ruin of the soil. Whereas, this deadly poison might not only have been removed, but converted into important economical purposes; while the soil, by being stripped of it, might have been converted into a fertile meadow, in place of a barren waste.

destitute of earth, and composed of a congeries of vegetable fibres, which hold water, like a sponge, in a sluggish state, fit to suffocate, not to feed, land vegetables. Soils capable of fertility are composed of two or more of the primitive earths, with a mixture of decayed animal or vegetable substances. It is the action and reaction of these ingredients on one another, and on the water that falls on them, that furnish a proper residence for the roots, receive the influence of the atmosphere, and, with this aid, prepare the moisture in that state of minute division in which alone it can support the growth of land plants, by conveying to them the dissolved vegetable food. These qualifications are *wanting in peat*, and, as it does not yield to corruption, growing plants can derive no food from its spoils."

In this account, three causes are assigned for the sterility of peat; and there can be no doubt that they all co-operate to communicate this quality.

1. That it is *destitute of that mixture of different earths, which enter into the composition of other soils*. This is strictly true, in general. Most fertile soils contain a proportion of the following earths, besides vegetable matter; cilicious, argillaceous, and calcareous earth. For the most part, few mosses contain such a mixture. In some, however, an equal proportion of all these earths may be detected, as in the most fertile soil; yet the former is barren, though the latter is productive. It is obvious, there-

fore, that the sterility of moss is not *altogether* owing to the *want* of such a mixture.

Nay, it would appear, from the experiments of the same judicious author, that *without any mixture* of these adventitious earths, moss may be rendered fertile. For he adds, "I made steam of boiling water pass through a flower-pot, loosely filled with peat, for some hours. The colour was changed into a deeper black, and the conformation was altered. Grains of oats, planted in this pot, produced two or three stalks from each grain, bearing *ripe* seeds; whereas, in *pure* peat, which had not been exposed to *steam*, the plants were weakly, and seldom came to the *ear*, and that ear was *never full*. I filled another pot with some moss, which had lain exposed to all the vicissitudes of the season for nearly 15 months; this also produced several good stalks, with tolerable ears, and *ripe* seeds."

Here moss is rendered fertile by two different ways, *without any addition*, or *mixture* of the *different earths*, which enter into the composition of other soils. The *want* of these, therefore, cannot account for the sterility of that substance; nor, on the other hand, can the presence of them always restore it, or render it fertile. For some mosses, as has been said, may be found, containing the same proportion of these earths with other soils, and yet they are very sterile when newly turned up. There must, therefore, be other causes for this quality: Accordingly,

2. Mr Nasmith observes, that the *sluggish state in which the water is held in moss,* may be another cause. From the foregoing statement, it appears that this water is impregnated with many vegetable *poisons.* May not the sterility of moss, therefore, be ascribed to *these,* rather than the *sluggish state* in which the water is held?

3. He judiciously assigns another reason for the sterility of moss, *that it does not yield to corruption.* This is a clear and correct account of the subject. The consequences of its being arrested, in the early stages of the fermentative process, and the causes why it must be sterile as a soil, while in that state, have been mentioned already. See Sect. II, III, IV, of this Essay.

That the mechanical structure of peat, in its natural state, (the tenacity, insolubility, and impervious quality of it) are all hostile to vegetation, cannot be doubted; and till these be removed it will remain sterile: That it becomes often too light, loose, and porous, after being reclaimed, and, by this means, too *wet* at one time and too *dry* at another, as a soil, is equally certain; and that a mixture of *adventitious earths,* in this case, is of *vast advantage* to remedy these defects, cannot be doubted *. But the latent

* Some ingenious gentlemen have supposed that the sterility of moss is chiefly owing to the plants of which it is composed. On analysis, they suppose that aquatic plants contain a smaller proportion of argillaceous, cilicious, and calcareous matter, than other vegetables. This may be true; but it is not adequate to account for the *absolute sterility*

cause of sterility must be looked for from another quarter than the mechanical structure of the moss, or the want of this mixture of other earths.

From the foregoing view of the subject, we may conclude, that the following causes may be assigned for this quality:

1. That the vegetable matter, of which moss is composed, has been secluded from the atmosphere.

2. That on this account, that matter has been arrested in the early stages of the fermentative process.

3. That the vegetable acids, and extractive matter that abounds in it, are hostile to vegetation.

4. That the various gases with which it is impregnated, are equally unfavourable.

5. That the bituminous oil it contains may occasion sterility.

6. That the mineral acids, and

7. The salts they form, in some mosses, are the chief causes of this quality *.

Sir James Hall, Bart. of Dunglas, whose zeal in promoting the interests of agriculture is only surpas-

of some mosses; for these aquatic plants, which contain the smallest proportion of adventitious earths, when they are subjected to the putrid fermentation, furnish a rich soil and manure. And, on the contrary, land plants, which contain the greatest proportion, when they are immersed in moss, become sterile. Even some mosses which contain a great proportion of such earths, are barren.

* No notice is taken of the sulphur which exists in many mosses. The reason of this is, that it is seldom, if ever, found in a simple state, but in the form of sulphuric acid, or the salts which it forms.

sed by his talents as a philosopher, makes the following judicious observation, in a letter to me, in January last:

"*The most important circumstance with regard to peat moss, is, to determine what chemical difference there is between that substance, in its natural state, and the fertile soil produced from it. Whether this difference is brought about by the* ADDITION *or* REMOVAL *of some substances. In this view, a well conducted analysis of both promises to be of great value.*" Nothing appeared to the author more judicious than this plan; he looked to it as the polar star to direct him in the investigation of this branch of the subject. With this view, he has tried a variety of experiments on different kinds of peat moss.

The result of these, however, was by no means so satisfactory as he expected; and the expence, and still more the time, and accuracy, requisite to carry on such experiments, are considerable. But there is still a greater obstacle in the way; and that cannot easily be removed. It is this; *that of all substances, different mosses differ most in their chemical qualities. The causes of sterility are different in their nature, and still more in the proportion in which they are detected in different mosses.*

From all, hydrogen and carburetted hydrogen are evolved, in a much greater proportion than from vegetable mould, bulk for bulk; but the relative quantity of these gases is sometimes *tenfold* greater

in one species than another. Soft fibrous peat, in all cases, yields a small, and black, and highly bituminated peat yields uniformly a great proportion of these gases. From all, too, a bituminous oil may be extracted ; but the quantity differs as much in different species of peat, as that of these gases. All yield an acid liquor ; but the acidity differs equally in different peat mosses. All yield certain salts ; but some give one species and others another ; some in very small, and others in a vast proportion.

Analysis, therefore, is not only a slow, difficult, but *uncertain* method, of ascertaining the causes of the sterility of *different* mosses, unless *every species* of that substance be subjected to this process. Even in this case, the result of the most correct, careful, and expensive experiments, would not be satisfactory. For it would prove, that different ingredients, and different proportions of the same ingredients, were the causes of sterility in different mosses. This is certainly the result of those experiments which the author has attempted to make. And although he has reason to conclude, that the causes above assigned are the occasion of the sterility of *all* moss, and constitute the *chief* difference between that substance and vegetable mould, yet, without a distinct analysis of *every species* of moss, it is impossible to ascertain the *predominant* cause of this quality in any *one*.

On this account, he, with some reluctance, relinquished this plan of proceeding, however ingenious and correct it may appear to be, and resorted to

another, much more simple, and by far less expensive, though equally, if not more satisfactory.

Concluding that the acids and gases, and bituminous oil and salts, which abound in peat, were the causes of its sterility, and finding that many of these were soluble in water, he resolved to try the effects of *solution.* He concluded, that if all of these vegetable poisons were found to *be soluble*, they might, by this means, be separated from that substance. To ascertain this, the following experiments were made:

Pieces of new dug wet moss were broken down, and put into a pot, perforated at the bottom, through which water was permitted to run, or rather trickle slowly. In a very short time, all these parcels were cured of their *sterility*, and reduced to a soil, capable of rearing and ripening grain. Warm water operated more speedily. And a current of steam had the same effect.

Thus far the experiment succeeded, and in no case did it fail. It still remained doubtful, whether the vegetable poisons were *removed entirely*, or had undergone such changes as rendered them innocent. To ascertain this, the following plan was adopted. The soluble matter, thus extracted, was examined by the following tests. To try if it contained any *acidity*, chalk was put into this liquid. In every case, an effervescence ensued, and in some it was considerable. On the contrary, though chalk was mixed with the peat that remained in the pot, no effervescence ensued.

The author concluded, therefore, that the *acidity* of that substance was removed by *solution*. When the muriat of tin was applied to this solution, a copious precipitation took place. Whereas, though fresh water was added to the peat earth in the pot, this test occasioned no precipitation in the liquor then obtained from it. From this he concluded, that the *tanin* was also carried off in solution. When the soluble matter first obtained from the moss was distilled, it discharged a vast proportion of *hydrogen*, and *carburetted hydrogen*, whereas the peat earth in the pot, by the same process, yielded only a *small* proportion. From this he concluded, that these deleterious *gases* were also discharged by solution. When this liquid was slowly evaporated to dryness, the residuum, in this case, contained a considerable proportion of bituminous oil; whereas the peat earth in the *pot*, yielded only a *small* proportion. From this he concluded, that when peat is newly dug, the bitumen in it is partly soluble in water. The residuum of this liquid was also found to contain a considerable portion of the salts which the peat, in its original state possessed. Whereas the peat earth, in the pot, contained a very small proportion. So that these salts seem also to be *soluble* in water, when peat is *newly dug*.

On the contrary, when the same new dug moss was thoroughly *dried* and converted into *peat*, he found it entirely *insoluble*, not only in *cold*, but in *boiling* water. Nay, though exposed for months,

in the steam of a *boiler*, in a fire engine, it remained almost in its original state.

These simple experiments are suggested, that others may repeat them. That is in the power of every one. And this plan seems to be preferable to analysis, not merely because more *simple* and less *expensive*, but *chiefly* because little or none of the gaseous matter is allowed to escape. By combining with the water, these gases are retained. The whole elementary principles of the moss may then be afterwards separated and examined *apart*, and the proportion of each more easily, and perhaps as *accurately*, ascertained.

That the acids, and gases, and salts, should be *soluble* in moss, when recently dug, seemed to him less *surprising*. But that the *tanin* and *bituminous oil* should be so, appeared at first more unaccountable; especially as they were entirely insoluble in water, after the peat was *dried*. This difficulty, in some measure, disappeared, when he found that the latter was always in combination with the *volatile alkali* in the peat when newly dug. By this combination, the bituminous oil formed an impure *soap*, or *savonule*. On this account it is *soluble*. Whereas, by the volatile alkali being discharged, and a considerable portion of hydrogen evaporated by *drying* the *peat*, and much oxygen also being *absorbed*; that oil, by these changes, assumes the concrete appearance and insolubility of bituminous matter. The tanin, too, and the gallic acid, by uniting with the *metallic*

particles, form insoluble compounds during the process of *drying*. By this means, the whole ingredients *partake* of this *insolubility*, when peat is *thoroughly dried*.

It is of importance to add, that in alkaline solutions *, even *dried* peat becomes soluble. But the experiments to prove this, and the important conclusion to which it leads, will be detailed in a subsequent *Essay* on *peat moss*, as a *soil* and a *manure*.

SECTION VIII.

GENERAL CONCLUSIONS.

1. That all peat moss is more inflammable, more antiseptic, more tenacious, and contains more acidity than vegetable mould, though originally composed of the same materials. That it is also more deleterious to living animals, and much more sterile as a soil, than that matter. But all the varieties of bitumens, whether solid, liquid, or aeriform, are possessed of the same qualities. All are inflammable. All operate

* The single, double, and treble solution of potass and soda, were used in these experiments. The first was weak, the second stronger, and the third exceeding strong. Different species of peat require different degrees of strength in the solution, in order to render them soluble.

as antiseptics. All are of a similar colour. All are tenacious. All are hostile to animal life. And all of them occasion sterility. Even in this view of the subject, therefore, the alliance between peat moss and bituminous matter may still be traced. This consideration corroborates the conclusion that they are homogeneous in their origin *.

2. We may conclude, that

However unlike moss may be to vegetable mould, and however different the qualities of these two substances may appear to be, this is no argument against the vegetable origin of either; for the different appearances of these substances, and the distinct chemical qualities they possess, may all be accounted for, in consistency with that hypothesis.

3. We may conclude,

That different mosses must be possessed of very different degrees of those qualities which distinguish that substance from vegetable mould. This difference does not altogether depend on the original materials of which moss is composed; but partly, or chiefly, on the different changes and combinations formed, during the decomposition of these materials. Hence some are highly inflammable, while others yield little or no flame. Some act as powerful antiseptics, others possess less of that quality. In some,

* It is an additional proof of this, that similar salts are detected in both substances, by destructive analysis. The sulphats, and phosphats, and muriats, and gallats, and carbonats, discovered in different kinds of peat, may be found in coals of different kinds.

the acidity is strong, in others scarcely perceptible. Some are utterly sterile, and others produce a few useful plants.

But the different kinds of moss, and the mode of classifying these correctly, is reserved as the subject of another essay.

ESSAY IX.

ESSAY IX.

ON

THE DIFFERENT KINDS

OF

PEAT MOSSES,

AND THE CLASSIFICATION OF THEM.

THOUGH all peat moss be of vegetable origin, yet the situations in which it is formed, the plants of which it is composed, and the state in which it is found being different, it is reasonable to expect that one moss should differ from another in its appearance, qualities, and the uses to which it may be made subservient. This difference may often be detected by the naked eye; whether the moss be in the pit, or dug and dried, or burning, or reduced to ashes.

The various colours that substance assumes, and the external appearance of it, mark this difference. Some are of a bright yellow colour; others brown, or jet black. Some are composed of a congeries of vegetables in an organized state; in others, few or no traces of organization can be seen. Clay, sand, and shells, may be detected in some; in others, no such mixture can be discovered. Some are soft and

greasy, like butter; and form a hard, brittle, tenacious peat, almost like coal; others are loose and friable like mould. The water squeezed out of one moss is of the colour of amber; of another, of claret or port wine; and of a third as black as ink. In some cases this water effervesces with chalk, in others not. Sometimes it leaves a copious sediment by evaporation, which is highly inflammable. In other cases the sediment is small and scarcely inflammable. Some are covered with a rich luxuriance of aquatic plants, others are utterly bare, barren, and destitute of vegetables on their surface.

The distinct qualities of which mosses are possessed likewise mark this difference. Some are light, porous, and spongy, either when newly dug or dried; others are compact, hard, and heavy. Some when dug and dried are highly inflammable; they burn with fury, emit much flame, last long, and yield an intense heat, and a great quantity of ashes; others are scarcely inflammable, and yield little flame or heat, and few ashes. The flame of some is bright white, of others blue. The smoke of some is always safe, and in some cases salubrious; that of others is dangerous, and sometimes fatal. The smell of some is strongly sulphureous; of others it is bitter, fetid, and extremely nauseous; and of others, acrid and pungent. Some spontaneously take fire before or after they are dug and dried; others will scarcely kindle or catch fire at all. The ashes of peat are equally different in colour, consistency, and chemical

qualities. Some are white, others grey, yellow, red, or black. Some are very light, others heavy. Some are attracted by the magnet, others not. Some contain many saline substances, others few. Some operate as a most powerful manure to moss or other soils, others are almost useless.

To suppose that a substance so heterogeneous in *appearance*, and possessed of such different qualities, constitutes only one species of matter, all equally fit for a fuel, or a soil, or manure; or to conclude that there are no distinct features, by which mosses of different qualities, and adapted to different uses, may be discriminated, appears unreasonable and inconsistent with analogy.

In whatever point of view this substance is considered, whether as a *useless waste*, or as capable of being converted to *some* economical purpose, it is of importance both to the natural historian and cultivator to ascertain, if possible, the distinct species of which it consists. Thus alone can either speak clearly and correctly on the subject.

To detect a *few* of the most *palpable* features by which different mosses may be distinguished, when in a *wet* or *dry* state, or *burning* and *reduced to ashes*,—to arrange these in distinct *classes*, and assign an *appropriate name* to each, is the object of this essay. The subject is difficult. The descriptions given may be found incomplete. And the features fixed upon may not be fully or clearly stated. A

correct chemist may detect many more. The author means only to point out the *most palpable**.

SECTION I.

Various attempts have been made to ascertain distinctly the different kinds of peat moss, and to classify them under distinct names. The descriptions that have been given of this substance, by different authors, and the classifications they have made, appear to be indistinct and indefinite.

Some seem to have considered

The colour as a sufficient ground of distinction. In their descriptions, therefore, of the different species of moss, they have attended to little else. Degner describes the Dutch mosses as composed chiefly of three kinds; black, red, and redder. Ribaucourt, delineates those of France in a similar manner; as, white, brown, and black. Dr Leigh speaks of the mosses of Lancashire as consisting of white, grey, and black. Even Mr Kirwan appears to consider

* It is deemed unnecessary to detail the different experiments he has made with a view to ascertain the discriminating qualities of different mosses. They are very simple, and could not be interesting.

the colour as a ground of classification ; he calls one brown, another yellowish-brown, and another black.

Others have classed the varieties of this substance not so much by their colour, as their

Density or weight. Girard describes the moss of the Somme as either loose and friable, or homogeneous and solid. Degner sometimes speaks of the Dutch mosses in similar terms; he calls one species light and spongy, another somewhat heavier, and a third heaviest of all. Du Hamel calls one species of moss loose and friable, and another very bituminous.

Some have supposed, that the difference between these different species depends on the

Plants of which they have been originally composed. Dr Walker appears to have rested his classification chiefly on this ground. He distinguishes moss into the following kinds; wood peat, flow peat, heather peat, gramineous peat, consumed peat, and water-born peat. And Degner, near the conclusion of his work, seems to adopt a similar mode of classification. He says, that *mossy* peat, (*i. e.* composed of the different species of the *musci*), *grassy* peat, *aquatic* and *ligneous* peat, ought to constitute the distinctions of that substance.

Others seem to think that the only rational and useful classification of that substance ought to depend on the aspect it presents to the cultivator, or the plants that *now* grow on its *surface*. Mr Aiton, in

his last published treatise, adopts this mode of arrangement.

Some of the early Dutch writers have made a more fanciful distinction. They considered peat moss as a *plant sui generis*. Dr Anderson adopts this idea, and seems to consider it as constituting a most important distinction into *living* and *dead moss*. His words are: "Of all these facts, the most important is, that which respects the distinction between quick and dead moss; and therefore it ought to be particularly attended to; a fact which is universally known and recognised by every labourer in a peat country; though it has been totally overlooked, or in a great measure disregarded, by every writer he knows of; an omission nearly similar to that of a man, who, undertaking to treat of the physical growth of trees, and the distinctive qualities of saw-dust, should think he had fully performed his task, by entering into a discussion of the mechanical uses, and other peculiarities, of timber only."

The consequence of these various opinions, and very different modes of classification, is obvious. We are utterly at a loss to speak on the subject, so as to be understood. We know not what constitutes the difference that exists between the different kinds of peat. And we are equally at a loss to know the number as well as the nature of the different species of which that substance consists. According to some of the above ingenious authors, there are only *two*,

others suppose that there are *three*, and some make *seven* distinct classes. There must, therefore, be some defect in the above mode of classification.

SECTION II.

It appears, that neither colour, nor density, nor weight, furnish a distinct or sufficient ground of classification. The shades of colour are so delicate, and the gradations so imperceptible, that it is impossible to say where one colour ends, and another commences. The different degrees of density and weight seem to be equally undefined.

Yet all these distinctions may be of use in *describing* the different species of moss, if that substance be subject to specification. They ought, therefore, by no means to be *entirely discarded*. For in a description of any substance, the colour is a circumstance which must arrest the attention. The density, too, and still more the specific gravity, ought to be attended to. All these, however, are only *qualities* or *adjuncts*, which, though they may help us to *describe* different substances, when *taken together*, cannot, when considered *separately*, or *apart*, furnish a proper ground for classification. Yet, when we say that any species of peat is white, brown, or black, of the density of coal, or of any other sub-

stance, whose density is known, or that it sinks in, or is specifically heavier than water: We speak in a language which is clear and intelligible. But if we merely say, that it is white, or brown, or black, or that it is of a certain specific density or weight, without any *other* discriminating quality, it is obvious that such a description must be very indefinite.

The different plants detected in an organized state in moss, cannot be considered as a just ground of classification. At least, it is liable to the following objections.

No one moss in existence is entirely composed of any *one species* of plants. Nor can it even be said, that *one genus alone* constitutes, exclusively, any particular moss. None, for instance, are *entirely* composed of *ligneous* plants, far less of *oak*, or *fir*, or *birch*, or any species of tree. None, therefore, can properly be called *wood* peat. If, under this description, be included all such as contain ligneous plants in an organized state, it is obvious that this description is very indefinite. For nine-tenths of the mosses in the world must be included in it, however different in their chemical qualities. If it be understood as descriptive only of such mosses as contain nothing but ligneous plants, it is equally defective; for none such exist. An almost endless variety of aquatics enter into the composition, even of those mosses in which ligneous plants most abound.

The same objection lies against all the other distinctions founded on this principle. No moss is en-

tirely composed of *grass*, or *bent*, or *heath*, or even of the *musci* alone. None can, therefore, properly be called *gramineous*, or *benty*, or *heathy*, or *mossy* peat. Nay, there are few that can be said *chiefly* to be composed of any *one* of these species. For the most part, it is extremely difficult to ascertain, precisely, which species of plant prevails most.

If, therefore, moss must be classified according to the vegetables of which it is composed, it is obvious, that, in order to be correct, it ought to bear the name, not of *one* plant only, but of *all* that enter into the composition of that substance; or to be divided into as *many kinds* as there are species of plants in it. On this supposition, there may be several hundred kinds of peat.

But the chief objection to this mode of classification is, that it is not only incomplete and impracticable, but of little or no use. Whether we consider moss as a soil, or a manure, it is comparatively of little importance of what plants it is composed. For all vegetables, whether ligneous or aquatic, contain very nearly the same elementary principles. The moss, when completely formed of all, or any one species, therefore, must be homogeneous. For, however different these plants may be in their appearance and conformation, when in their recent growing state, when they are decomposed and reduced to their elementary principles, and then converted into moss, they must present a similar appearance, possess similar qualities, and form a similar substance.

The distinction, which Dr Anderson adopted, into living and dead moss, appears to be founded on a hypothesis that cannot be maintained, viz. that this substance is a growing vegetable *sui generis*. Not one *vestige* of this appears in any one moss. The *genus* of every plant of which that substance is composed, sufficiently distinguishes itself. To suppose moss, therefore, to be an organized growing vegetable, is utterly inconsistent with the analogy of nature in every other case. No plant nor tree is composed, like moss, of a congeries of other vegetables, in an organized state.

Mr Aiton, therefore, in his last treatise, has discarded all the above modes of arrangement. He has adopted one which appears to be new. According to his plan, "there are only three species of moss that require to be cultivated in its own way, viz. hill moss, bent moss, and flow moss." Of each of these he gives a specific description. Without attending to the colour, density, gravity, or plants of which the moss is composed, he describes and distinguishes each of the above kinds by the plants that now *grow on its surface*.

It is needless to observe, that this arrangement is equally deficient and indefinite as those mentioned above *.

There are other distinctions which may be of use. Most of these are so clearly defined, and may be so

* The following Table, given by that author, is sufficient to shew this:

distinctly described, that there is little danger of confounding one species with another; and each of them being different in their chemical qualities, requires different treatment by the cultivator, whether considered as a soil or a manure*.

I. Hill Moss Plants.		II. Bent Moss Plants.	III. Flow Moss Plants.
1. Erica vulgaris,	Heather.	——	do. do.
2. Hypnum squarrosum,	Yellow dry Fog.	——	do. do.
3. Sphagnum palustre,	Marsh Fog.	——	do. do.
4. Polytrichum commune,	Goukbear.	——	do. do.
5. Juncus squarrosus,	Stool Bent.	ditto	——
6. Nardus stricta,	White Bent.	ditto	——
7. Tormentilla,	Tormentil.	ditto	——
8. Carices,	Sedge Grasses.	ditto	——
9. Holcus lanatus,	Soft Grass.	ditto	——
10. Anthoxanthum odoratum,	Vernal Grass.	ditto	——
11. Agrostides,	Bents.	ditto	——
12. Festucæ,	Fescues.	ditto	——
13. Lichen rangiferinus,	White Fog.	——	——
		14. Scirpus cæsp. Club-rush.	
			15. Bryum hyp. Drab Fog.
			16. Erioph. polys. Cotton Heads.

According to this Table, hill moss contains all the plants which grow on the other two kinds, excepting three. The first four plants are common to the first and third species; the next eight are common to the first and second.

To suppose, therefore, that this *small* difference should constitute a ground of arrangement, either intelligible to the natural historian, or useful to the cultivator, appears doubtful.

* It is with the utmost deference that the author differs in opinion, on this subject, from these distinguished gentlemen; and it is with equal diffidence that he now suggests a new mode of classifying mosses, that may probably be found in the issue to be equally indefinite, indistinct, and incorrect, as any that has already been suggested.

If, however, it be the mean of exciting the attention of chemists, and of such men as are better qualified to discuss the subject, or of suggest-

SECTION III.

Geanthrax appears to be the appropriate classical name for every species of this substance. *Peat moss* is the appropriate name in English. M. de Luc, in one of his letters, justly observes, that it corresponds to the French word *tourbière*, and that peat corresponds to *tourbe*. The latter, therefore, ought only to be used when speaking of *dried peat;* the former is descriptive of the same substance in its natural state, before it be dug, or dried.

Poiret has made a distinction of this substance into *two* kinds; he calls the one fibrous, the other compact. As this distinction seems to be well founded, it may be proper to state it fully, and to attempt a description of both these varieties.

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1. *Fibrous Moss.*

His description of this genus is distinct. "It is composed of the roots, and stems, and branches of *marshy* plants; of course, the moss is a loose, light, porous, elastic substance, retaining the plants of which it is composed, in their original organized state."

ing to them a more correct and classical mode of distinguishing the different kinds of that substance, his object will be attained, and a most essential service may thus be done to the public.

He describes, too, the distinct plants that may be detected in this genus: "Roseaux, scirpes, carex, souchets, joncs, iris, mousses, hypnum, et sphagnum." The two last, he says, are the most prevalent. Being mostly of a "dry and coriaceous nature," he observes, "that they are not soon liable to disorganization. Their roots and stems retain their form for ages. Hence, though covered over with an alluvial soil to a considerable depth, and though the formation of the moss may be traced back to the remotest ages, such mosses exhibit these plants in their *original fibrous form.*"

The characters of this genus are sufficiently marked, and may be easily distinguished.

When lying in its *natural state,* it is always a soft, porous, spongy, and very elastic substance, composed of a variety of plants, in an organized state. The roots, stems, branches, and leaves, and often the seeds of every species of which it consists, may be distinctly seen. It is frequently so tough and elastic, that the finest edge tool, or spade, can scarcely cut it. The water squeezed out of it generally effervesces with chalk, and when evaporated, leaves little sediment.

When *dug and dried*, it is a light-coloured, porous substance. Sometimes that colour is a dirty white, or bright yellow; seldom is it brown, and never black. This genus is always specifically lighter than water; and it may be torn asunder easily; but it is so elastic when dry, that though it yields to

compression for a time, it soon reverts to its former shape and size. When immersed in water, it absorbs that liquid readily, and becomes like a wet sponge.

When *burning*, it emits a light-coloured smoke, little flame, and little heat. It does not last long, or leave a great quantity of ashes.

These *ashes* are generally of a whitish grey colour; they seldom become red when exposed to the air; they are very light; they contain few salts, and are scarcely attracted by the magnet.

If these distinct features be considered as sufficiently marked to constitute a distinct genus of moss, it must comprehend under it a variety of species; and a vast extent of the surface of the earth is covered with it. The gramineous peat of Dr Walker, the groos, or hey torf of the Dutch, the flaw peat, or, as it is called in Holland, locke, or wooly, draetagtic, or filamentous; or in Ireland, old wives tow; the leafy peat of Brongniart, the bouzin, or rushy peat of the French, the whole red bogs of Ireland, and probably the heath-peat of all countries, may all be considered as constituting so many species of this genus; at least, all of them may be called *fibrous;* for each of them is composed chiefly of vegetable matter, in a distinct organized state.

If so, this genus is perhaps of all others the most abundant. Most of the low-lying mosses in Britain, Holland, Bremen, France, and Ireland, are of this description, especially on the *surface*.

SECTION IV.

Opposed to this, M. Poiret describes another genus, which he calls

2. *Compact Moss.*

His description of it is sufficiently distinct. He says, that "it is not found in *shallow* marshes, but in the bottom of *canals*, and deep *pools*. It is not composed of similar plants with the former, but chiefly of the following aquatics; the conferva, lemna, byssus, potamogeton. These plants being mostly of a tender and pulpy texture, having neither coriaceous nor ligneous fibre, are more speedily decomposed than marshy plants. By this means they form a thick black pulp, which sinks to the bottom of the lake or pool. The moss which is thereby formed he calls *compact*; because, though soft and slimy when dug, yet by compression, or when dried, it is at last converted into a solid, compact substance, which contains few, and sometimes no vegetables, in their original organized form."

Such is his description of this genus. It is sufficiently distinct from fibrous peat; it differs in colour, consistency, and chemical qualities, from it.

In its *natural state*, it is less elastic, and much more compact, and darker in colour than fibrous moss. It is more easily cut with an edge tool, and

it contains few vegetables in a state of organization. It feels soft and pulpy to the touch; and the water squeezed out of it is of a deeper dye, and yields a more copious and inflammable sediment by evaporation.

When *dug and dried*, it is of a brownish black colour; and though soft at first, it soon becomes a solid, hard, tenacious substance, much more compact, much heavier, and much less elastic than fibrous peat. Though immersed in water, it will not absorb that liquid.

When *burning*, it emits a darker smoke, and brighter flame; it lasts much longer in the fire, and yields a more intense heat, and more ashes.

These *ashes* are generally darker in colour than those of fibrous peat. When exposed to the air, they become yellow, or red, in consequence of the iron they contain. On the same account, they are attracted by the magnet, and much heavier than the ashes of the other genus mentioned.

If these distinct features be found to be sufficient grounds of classification, it is obvious, that under compact moss a variety of species must be included; at least, it has been called by different names. The bent moss of Mr Aiton, (according to his description of it) the baken peat which Dr Walker describes, the mud-turf of the Irish, and the mire-black of Loch Neagh, may all be included under this genus. The tourbe limoneuse of Brongniart, and the lowest strata of the British mosses *in general*, and that

which is discovered in the bottom of lakes, and pools, and canals, over the greatest part of Europe, may be considered as of this description.

Whether moss be intended for a soil or a manure, the above distinction may be of use; for it is obvious that these two genera must require very different treatment, in order to reduce them to either of these economical purposes.

It is a distinction, too, which has this obvious advantage, that the practical farmer can be at no loss to discriminate those two kinds. The difference that exists between them is so palpable as to be obvious at first sight. When we speak of these two kinds, we speak in a language intelligible to every cultivator; in a language, too, which not only the peasant can understand, but which the natural historian must allow to be correct.

For between these two distinct genera of peat, there is the same difference as between surturbrandt and coal, or between a dead carcase, where every member is yet entire, and the dust of which it is composed, when reduced to a state of disorganization. Between these two extremes in animal matter there are indeed many intermediate stages, but none of these are so distinctly defined as to furnish ground for classification. It is precisely the same with the vegetable matter of which moss is composed. Between a state of organization, where the vegetable structure is entire, and that of total disorganization, where it is evanescent to the naked eye, there are

also many intermediate stages. But none of these can be fixed on as a ground of distinct classification.

If the above distinction be correct, we are at no loss to know of what materials each of the above genera is composed. The fibrous peat consists of a congeries of vegetable matter mostly in an organized state. The carbon contained in the fibres of these vegetables, has never yet been wholly dissolved. Less soluble carbon therefore enters into the combination of this, than of compact peat. The former may therefore be expected to contain less bituminous matter, and on this account it must be less inflammable. This is literally the case. But even in fibrous peat, a part of the carbon, especially that which is contained in the acids, and oils, and gums, and tanin, may have become soluble. By combining with the hydrogen of these vegetables, it must form an inflammable bituminous substance. The most fibrous peat, on this account, must be inflammable, and contain a small portion of oleaginous matter. And it is reasonable to suppose, that, by continual maceration, and the operation of those chemical agents which are found in moss, the whole fibrous structure of the vegetable may be ultimately destroyed, and the whole carbon it contains rendered soluble. By this means, the fibrous may be at last converted into compact moss.

This last therefore consists of the same elementary principles with the first. The chief difference between them is, that these elementary principles have

all been separated and combined anew in compact peat, thereby forming a greater proportion of resino-bituminous matter, such as has been detected in moss, surturbrandt, and the substance which accompanies it; whereas only a part of these principles have been set free from their combinations in fibrous peat.

It is not, however, insinuated that there can be no objections to this distinction. On the contrary, it is allowed on the one hand, that the most fibrous peat may contain some vegetable matter entirely decomposed, and on the other, that the most compact may contain some in a state of organization. It may be said, therefore, that the same objection may be made to this distinction, as to that which depends on colour, consistency, and weight. The gradation, in the one case, it may be urged, is as delicate and insensible as in the other; and it may therefore be as difficult to draw the precise line which separates these two genera.

To this it may be replied, that, for the purposes of agriculture, this *precision* is not requisite. And the distinct characters and different appearances of these two genera, are so clearly defined, that there is little danger of any practical error of this kind.

Many, indeed, seem to suppose, that there is no occasion for any further distinction than the two genera above described. The authors of the Edinburgh Encyclopædia appear to be of this opinion. They consider all moss as of two kinds. And, according to

their description, these correspond with the above. Their *white* moss is, in every respect, the same with that which Poiret calls fibrous. And then *black* moss corresponds with what he calls compact.

When we consider peat moss, however, as capable of being converted into a soil, or a manure, there appear to be *other* grounds of distinction. For some mosses are possessed of *chemical qualities* highly *favourable*, or equally *unfavourable*, for either purpose. It may not, therefore, be improper to suggest some other distinctions that ought to be made, when speaking of that substance.

SECTION V.

3. *Highly Bituminated Peat.*

THIS is indeed a compact moss, and generally contains few or no vegetables in an organized state. It differs chiefly, if not solely, from the above genus, by the greater quantity of bituminous oil it contains; yet this one ingredient imprints on it such distinct characters, that it is easy to discriminate the difference that exists between them.

Bituminous is always black, like compact moss; but the former, when *newly dug*, feels softer, and

more *greasy* to the touch; it is, too, much more unfavourable to vegetation; no plant nor shrub will vegetate in it. The water squeezed out of it is of a darker colour, resembling that of tar melted; and when evaporated, it leaves a much greater sediment, and more inflammable.

When *dried into peat*, it becomes not only black, but *glossy;* it is of a *resinous* lustre in the fracture; when held in the hand, it emits a fetid, bituminous odour; and it is so ponderous, that it sinks in water.

When *burning*, it emits a very bright *white* flame, like tallow or butter; it will even burn like cannel coal, when carried in the hand; when kindled, it is difficult to extinguish it; the smoke it yields is black, and very dense; it leaves few ashes when burnt. If sulphuric acid be poured on it, the effervescence is so strong, that it kindles into flame, and discharges, by this means, as well as by distillation, a vast quantity of hydrogen, and carburetted hydrogen. The proportion of oil obtained from it, in the last process, is sometimes equal to one-fifth, or one-third of its weight. An alkaline solution of this kind of moss resembles an impure *soap;* that of compact moss is less saponaceous.

This genus is by no means frequently found; yet in Scotland, England, and Ireland, many specimens of it have been discovered. The Ince-peat of Lancashire, the Cæspes bituminosus of Northamptonshire, (which Dr Morton describes) and that which

Dr Rutty found near Newberry, (see Ess. V. Sect. 4.) The greasy clods of Aberdeenshire *, and the glossy peat which Professor Robison found near John-o'-Groat's House, all belong to this genus. Probably Hassel moss, and that which is found in some parts of Loch Neagh, are of the same description, and most certainly that which Du Hamel describes, and Dumain analysed. The peat which Monardes says has been dug up from the bituminous marsh at Peru, belongs also to this genus. Some beautiful specimens have been sent to me, of a similar kind, from the Western Isles, especially Isla and Jura; and many may be found in the lowest strata of the mosses in this vicinity.

It is of much importance to consider this as constituting a distinct genus of moss; both because it is extremely unfavourable for cultivation as a soil, and because it is of much more value than any soil, for other economical purposes, which shall be mentioned in a subsequent Essay.

* The Rev. Dr Skene Keith, in reply to some queries sent to him, observes, " That these creeshy clods are not a distinct species of peat. They are found in the same pit with other peats, but generally in the hollowest places of the moss. It is an OILY substance, and so friable, that we can only get a *clod*, or part of a peat, of this kind."

J. Wing, Esq. steward to his Grace the Duke of Bedford, says, in another letter, " That in the fens of Lincoln, there is a stratum of moss called *Bear's grease*." From the description given of it, there seems reason to suppose that it is bituminous; but as the author has not yet got a specimen of it, he cannot assert this positively.

4. *Genus.—Moss Earth.*

Opposed to this genus may be mentioned moss, which, though once bituminous, is now stripped of bitumen. It is distinguishable from bituminous and compact peat, though it agrees with both in this one feature, that it frequently contains few vegetables in an organized state; yet it differs in external appearance and chemical qualities from both, in the following respects:

In its *natural state*,

It is always friable, like mould; they are tenacious.

It is pervious to water; they are impervious.

It is often found covered with succulent herbs; they seldom.

Worms, insects, and animals, can exist in it; in them none are found.

When dug and dried,

It cannot be formed into a solid hard peat; it is rotten and friable; they are tenacious. It burns with difficulty, yields little flame, little smoke, and a considerable quantity of ashes; they burn easily, with much flame and smoke, and fewer ashes.

When distilled,

It yields only a small proportion of oil, and discharges only a little hydrogen and carburetted hydrogen. Compact moss yields always a considerable portion of all these; and bituminous, double, and sometimes treble, the quantity of compact.

In one word, it differs as much from bituminous

moss, as blind differs from cannel coal; and it possesses so few of the distinguishing qualities of peat, and these in so small a proportion, that it never ought to bear the name of moss. It contains so few inflammables, so little bitumen, such a small proportion of the acids, and is so nearly allied to *earth*, that it cannot be said to be PEAT *moss* at all. It is what Mr Aiton justly calls *moss earth*, though, unfortunately, he applies that name to every species of that substance. By the Dutch it is called *Peat modh*, or *Turf modh*, and by the Scotch, PEAT MOLOCH, or rotten moss. By Dr Anderson it is called *dead moss*, while bituminated peat is called *quick*, or *living* moss.

It oftentimes is so black, so friable, and fine in its texture, that it cannot be distinguished from the very finest vegetable mould. Some specimens have been sent to me, which, in every respect, resemble the black rotten wood found in the heart of large decayed willow trees. It is uniformly less inflammable, less tenacious, less acid, less hostile to animals, and more fertile as a soil, than peat moss. In one word, it is peat moss partly, and sometimes completely, changed into mould; but being of the same colour, and the product of the same vegetable matter, it ought to be considered as still allied to that substance, and to bear a name expressive of that alliance. *Peat*, or *moss earth*, seems to be this appropriate name.

The situations in which it is found are easily marked. On the surface of many of the mosses in Europe it may be seen ; and the warmer the climate, it abounds the more in such situations. On the declivities of all the hills it may be detected ; especially on such as are exposed much to the influences of the sun. Even in low-lying levels it may frequently be found, especially on such as are occasionally, or often, overflown by rivers. Of all kinds of moss it is the most easily reclaimed, and converted into a fertile soil. Indeed, nature has already performed half the task. The acidity, tenacity, and bituminous oil which it originally contained, have been carried off ; and these poisonous qualities being removed, it is easily reduced to a soil. The process is already begun, and advanced to a certain degree.

How this operation has been carried on, we are at no loss to know. By the influences of the sun and air, and the alternations of moisture and drought, heat and cold, the vegetable matter it contains has been subjected to a process similar to the putrid fermentation. The superabundant hydrogen has been expelled, in the form of gas. The acids it contained have been washed away, in solution ; and the bituminous oil has been parly carried off by both these means. It is what that accurate chemist, Lord Dundonald, justly calls *oxygenated peat.* And if any species of that substance can be called *putrid*, it is this. The vulgar term, *rotten* moss, is by no means inapplicable to it.

SECT VI.

5. *Moss, mixed with calcareous matter*, constitutes another genus.

In its colour, characters, and chemical qualities, it differs from all of the genera above described. That difference, too, is so palpable, and this genus can be so easily discriminated from every other, that it ought to have a distinct name. *Calcareous* moss, perhaps, may be its appropriate appellation.

In external appearance,

It is generally of a *marly* mixed colour. White particles of lime, and sometimes shells, in an organized state, may be found promiscuously blended through the whole moss. At other times, this calcareous matter forms a distinct stratum, above or below, or intervening between the strata of it. In all these respects it differs, and may be very easily distinguished from fibrous, compact, or bituminated peat.

In chemical qualities, that difference is as great, and as easily detected. The water squeezed out of it is much clearer than that of any other moss.

It contains much less acidity, is less antiseptic than any of the above. It will not, like them, when newly dug, effervesce with chalk. It is not so soluble in this state as they are. The water of solution obtain-

ed from them is of a coffee-colour. That which proceeds from it is more clear, and contains less bituminous or inflammable sediment. The lime combining with the oil forms an insoluble compound in this case.

When dried into peat, and burnt, it may be easily distinguished.

It is of a colour distinct from compact, or bituminous, or even fibrous peat. It is more porous, though as heavy as the two former, and much heavier than the latter, and not so yellow in colour. The smoke it emits is not so dark or dense as any of the above; it has a distinct odour, and communicates a *tawny colour* to the skin. This is the case with the peat of Lismore.

Wood, exposed to this smoke, is covered with a dirty, grey, glossy varnish. That which is exposed to the smoke of the other three, becomes black, like ebony.

The *ashes* of this species may be distinguished from all these; for they are uniformly more bulky, more heavy, and whiter in colour. They effervesce with acids, and yield the sulphat and other salts of lime. By all these features, they may easily be distinguished from the ashes of fibrous, compact, or bituminous peat.

The *situations*, in which such mosses are found, have been described in the 4th Essay. They lie in levels adjacent to higher grounds, impregnated with calcareous matter, or containing shells, marl, or

lime-rock, and petrifying springs. Such mosses, too, as have been, at one period of their formation, extensive lakes, are often of this description. The peat of the island of Lismore is of the same kind.

It is obvious, that, as a *soil*, this genus differs most essentially from fibrous, compact, or bituminous peat, and even from moss earth. All these require *adventitious* manure; this genus requires none. It may, by a very simple and expeditious process, (which shall be described in a subsequent Essay) be easily converted into a productive soil, without the aid of any adventitious manure. The ashes it yields may not only serve as a manure to itself, but to other soils, of very different qualities. The value of these ashes frequently depends on the quantity of calcareous matter they contain, and the salts with which they abound.

The far-famed Berkshire peat, near Newberry, in *some* of its strata, is of this kind. The Secretary of the Berks Agricultural Society, in a letter to me, mentions the following circumstances, in proof of this: "The deep, hard, black peat, (*i. e.* compact, or bituminated) is generally cut for *fuel*. That part which is of inferior quality for *this* purpose, is burnt into ashes, for which there is a great demand. These ashes *effervesce* with vinegar; and the *greater* the *effervescence*, the stronger and better is the manure they yield."

From this account, it appears, that one stratum of this moss, *i. e.* the black peat, is probably compact,

or bituminous, and therefore fit for fuel. The other stratum, which is inferior for this purpose, certainly contains calcareous matter. This is placed beyond all doubt, by the analysis of Mr Headrick. He found, that " the Berkshire peat left a great quantity of ashes, and that they contained the following valuable salts: sulphat of lime, of magnesia, of alumen, and of iron." This shews that some of the Berkshire peat contains calcareous matter, and ought to be classed under this genus.

SECTION VII.

The consistency, colour, and chemical qualities of moss as a soil, sometimes depend on the mixture of *other* earths, as well as calcareous. And wherever this mixture takes place, such mosses ought to be classed under a distinct name, as they are possessed of different qualities from fibrous, compact, bituminous, or even calcareous moss.

Earthy peat mosses.

6. Such as are mixed with a considerable proportion of *clay* and *sand* are of this description. Though in the eye of the chemist and natural historian, they cannot so well be considered as consti-

tuting a distinct genus, yet they unquestionably claim this distinction, when considered as a soil capable of improvement. For they require a *different treatment* from fibrous, compact, bituminous, or calcareous moss; and when improved, they constitute a *different* kind of *soil*. This distinction is of equal necessity, when moss is considered as capable of being converted into a manure for other soils. For this genus requires to be prepared in a manner *totally* different from any of the other genera. And the manure it yields is possessed of different qualities, and adapted to different soils.

On these accounts the above distinction is suggested. The only difficulty in this case is, to point out the external characters and chemical qualities by which this genus may be discriminated. The following appear to be unequivocal, and such as the chemist and cultivator may easily ascertain.

In external appearance, it differs from all those described above. It is of a different colour from any of them. It is not *white* like calcareous, yellow like fibrous, or brown and black like compact or bituminous, but of a dirty *grey* colour. Its consistency is still more different. It is, when newly dug, more compact, and much heavier, than any of the above kinds. Clay or sand may be detected in it, sometimes promiscuously blended through the whole, and at other times forming strata on the surface or bottom, or intervening between the moss. It does not effervesce so much with chalk as compact or bituminous moss, but more than calcareous.

When dug and dried, it forms a very *heavy*, hard, but not a homogeneous peat. It is *parti-coloured*, being often a mixture of grey and black. When rubbed on iron, it causes a grating noise; and it is always so *heavy* as to sink in water. It frequently splits into *splinters*, and it may be much more easily *pounded* into *powder* than any of the above kinds. Less of it is soluble in alkali than any of them.

When burning, it emits little flame or smoke. It leaves by far the greatest *bulk* and *weight* of ashes. While bituminated peat will scarcely yield one twentieth part, and compact peat one twelfth, this often yields one *third* or *fourth* part of its weight of ashes. When a mixture of clay preponderates, the peat, when burned, resembles a *brick*. When sand prevails, it is apt to *vitrify*. In all cases, in burns with a more *intense heat*, and lasts *longer* than any of the above kinds. These distinct features are sufficient to discriminate this genus; and they seem to constitute a species of matter, as different from other peat as coal is from bituminous schistus, and it bears the same alliance to them, as these last-mentioned bear to one another. It is as easy to distinguish this species of peat from the bituminous, as cannel coal from schistus; or from fibrous moss, as schistus from surturbrandt. The appropriate name of this genus seems to be marked out by Brongniart, *tourbe limoneuse*, or in English, *clayey* or *sandy* peat. Or according to Ribaucourt, *earthy* peat.

The situations in which it may be found are clearly defined. In low-lying levels, on the banks of the sea, at the mouths of large rivers, it may be expected to abound. Accordingly, M. De Luc observes, that vast strata of it have been discovered along the Dutch coast. " In digging a well near Rotterdam, they passed through a stratum of moss, twenty feet deep, mixed with much *clay.* At the distance of a few miles, the same stratum, of the same depth, was discovered. At Amsterdam, fifty-one feet of moss, mixed with much *sand* and *clay*, formed the highest stratum." There can be little doubt, that this has all been *water-borne peat*, as Dr Walker calls it. That it has been formed on the higher grounds, and gradually deposited, by alluvion, along with the sand and clay of which it has been composed, there can be as little doubt. For M. De Luc observes, " that the sand and clay are the same which abound along the banks of the rivers on the higher grounds through which they flow." Junius accordingly describes a species of peat in Holland, which corresponds with the characters above-mentioned. " It is a *greyish* turf, so heavy that it sinks in water, and as hard as a brick. This is owing to the mixture of sand and clay it contains. Hence it is slow in kindling, but emits great heat, lasts long, and yields much ashes." The under stratum of the peat of Utrecht, is of a similar kind. Degner says, " that at the depth of ten feet, a sandy slime, mixed with moss, is laid open." The surface of Berkshire peat

seems to be of the same description. Dr Collet says, "that it consists of a meadow; immediately under this lies *clob*, or peat *earth*, compounded with *clay* and *earth*, and true peat. This clob is not so good a *fuel* as the moss below it. But it is better as a *manure*, when burnt to ashes." The Secretary of the Berkshire Society, in a letter to me, makes a similar remark. "I have in my possession, some acres of peat, which I burn into ashes, but I apprehend that the Berkshire peat is a very *different substance* from *what you mean to treat of*. Yours I apprehend to be a vegetable substance, while ours is supposed by some to be a natural *earth*, originally covered with water, as it lies on each side of the river Kesset; though others suppose it to be a collection of vegetable substances, which have undergone putrefaction, into which *particles of earthy matter* have been conveyed by water."

In a word, almost all the moss found immediately under meadow lands, is composed of a similar mixture of different earths. On account of this circumstance, they are covered with *grasses* on the surface, and converted into meadows. Ninty-nine out of a hundred of the meadows of Europe, have been formed originally from mosses by a *similar mixture* of sand, clay, and alluvial soil. Hence the subsoil is still moss in its natural state. The surface alone is covered with this alluvial mixture. And patches of moss may still be seen scattered over this surface. Why have not they also undergone the same change,

by the same means? Just because they are uniformly, as they must have been originally, higher, and therefore not liable to alluvion. Hence the surface of these patches consists of fibrous peat, without one particle of sand, clay, or alluvial soil. They are, therefore, still a bleak, barren, unseemly waste.

SECTION VIII.

7. *Pyritous*, or as Brongniart calls it, *vitriolic peat*, is a genus totally distinct from all those described above.

In its *natural state*, or when dug and dried, or even when reduced to ashes; in *all* of these it exhibits such distinct features, that it may easily be discriminated from every other kind of moss. Considered as capable of being converted into a soil, manure, fuel, or any other economical purpose, it deserves an appropriate name, as it constitutes a genus of moss sufficiently distinct from every other.

The following are a *few* of the distinguishing features of this genus; which are so palpable and obvious that they cannot be mistaken, even by the cultivator.

In external appearance, it differs little from bituminous peat. Both are soft, greasy, black, and pon-

derous. It is equally compact, when dried, as any other species.

It is, too, like bituminous peat, in its natural state absolutely *sterile;* or when applied to any soil it is destructive of vegetation. But it differs from that and every other genus in the following distinct features.

When *plunged into water*, it occasions an effervescence, and a considerable heat. Exposed to the *air*, or when turned over, it will spontaneously take fire, even though moistened with water. The odour of sulphur may be distinctly felt in this case. A white efflorescent *salt* may be often seen on the *surface* of it. This salt is of a very styptic and austere taste. It is so caustic, that it will corrode the skin of any person who handles it. The water squeezed out of it is black as *ink*. Though generally highly bituminated, it differs in all these respects from bituminous moss, which contains no pyrites.

When dug and dried, it forms, like that genus, a compact black, glossy peat, of a resinous lustre, and specifically heavier than water. But even in *this* state it may be distinguished from it. For when exposed to moisture and air, a white efflorescent salt is formed on the surface of the peat, similar to that which is detected on the moss in its natural state. No such salt is formed on bituminous peat which contains no pyrites.

When *burning*, it emits a black, thick, smoke, like the former. Yet during this process it may be

distinguished from it. The smell of it is strongly sulphureous. The smoke is deleterious, and may be fatal to living animals. Bomare supposes that this is owing to the sulphuric acid and sulphuretted hydrogen gas that are discharged. Sublimated sulphur may be seen in the chinks of the peat. In all these respects it differs from bituminous peat which contains no pyrites. It differs, too, in the colour of the *flame* it yields. That of the latter is of a blue, while that of the former is of a bright white colour.

When once kindled, it is much more difficult to be extinguished than any kind of moss. Even though plunged in water, it will continue to yield a slow singeing smoke, till it be reduced to ashes, which is not the case with bituminous peat. When charred, too, it will spontaneously take fire, if exposed to moisture and air, which is the case with no other genus of peat that contains no pyrites. And of all others it yields the most *intense heat.*

When *reduced to ashes* it still retains *some* of its distinct features. These ashes contain a far greater proportion of *salts* than any other kind of moss. They are, of course, more caustic. They are uniformly red, and a great proportion of them is attracted by the magnet, as they contain much iron. Of course, bulk for bulk, they are the *heaviest* of all peat ashes. And though, in its natural state, it is of all other mosses the most *sterile*, yet when reduced to *ashes*, it furnishes a richer manure than any other. Bomare observes, " that they are peculiarly excel-

lent for a top-dressing to low lying wet meadows. They destroy the noxious or useless weeds on the surface. They are far less expensive than any other manure. And they may be sown in moist weather on every kind of soil. The high grounds of Picardie, and the neighbouring provinces, never knew what it was to enjoy abundance of all kinds of fodder, till within these fifty years, that is, till they began to use the peat ashes of Picardie." It is needless to remind the reader, that this is a *pyritous* moss. The ashes of the moss of Beauvois, which is of the same description, he observes, "furnish an *excellent manure*, though the moss itself, when applied as a top-dressing, is *utterly destructive to vegetation*."

These characteristic features are sufficient to distinguish this from every other genus of peat. As a fuel, it is not *safe* to use it. As a *soil*, it is almost *irreclaimable*, and never can be improved without a most extravagant expence. As a *manure* the ashes of it may be extremely useful. And it will appear, in a subsequent essay, that it may serve *other* economical purposes, more important than any *one* or *all* of these combined.

It is not denied that compact, and still more bituminous peat, sometimes contains a *small* portion of pyrites. On this account it may be supposed that these genera may be confounded together. In reply to this it may be observed, that unless the quantity of pyrites be considerable, the moss will not exhibit

the *above appearances,* nor possess these distinct *characters.* It ought therefore never to be called pyritous, but when pyrites *abounds* in it, as it frequently does. To point out the *situations* where this is the case, were superfluous, as they have been mentioned already in the Fourth Essay. Suffice it to say, that this kind of moss may be more frequently found than is generally supposed. And it is of the utmost importance to the cultivator, and to all who attempt to use this substance as a soil, a *manure,* or *fuel,* to attend to this distinction, otherwise they may throw away much money in attempting to convert it into a soil, and lose much manure that might be made of it, by burning it into ashes. Whereas, if applied in any other way to any soil, it may prove absolutely destructive to vegetation.

SECTION IX.

There is still another genus of moss, distinct from all these, and possessed of different qualities. That has been called, by Brongniart,

8. *Marine moss.*

In many features it resembles those already described. It is generally fibrous, full of reeds, rushes, and aquatic plants in an organized state. Of this

description is the *braack* torf, or darry of the Dutch. Sometimes it is compact. That which is dug out of the bottom of the morasses in Holland is of this description. It is often bituminous, and sometimes even pyritous. Of this description are the mosses of the Somme. Calcareous earth, clay, and sand, sometimes enter into the composition of it.

If in *all* these respects it bears so near a resemblance to all these genera, why should it be distinguished from them, or be considered as forming a different genus? The chief grounds of this distinction are the following: that this genus is possessed of characters by which it may always be easily distinguished from every other; that it is unfit, and even *unsafe*, to be used as a fuel; that it contains the richest treasure of *manure* for other lands; that it may at the *smallest expence* of any be reclaimed as a soil; and that it may serve economical purposes to which *no other* kind of moss can be converted. On these accounts it ought to be considered apart, and have an appropriate name. By some it is called *marine*, by others *salt* or *braack* torf. Either of these appellations may be used; for both are descriptive of its distinguishing features. The former marks out the *situation* in which it is mostly found, and the *distinct plants* that enter into its composition. The latter is descriptive of the distinguishing *salt* that prevails in it. By these features it may at all times be distinguished from every other kind of moss. The

following additional circumstances may likewise be of use to prevent mistakes.

By its external characters it may be discriminated. It often contains *marine* plants, or such as flourish on the sea-shores. The mosses which Professor Lineck discovered along the coast of Spain were chiefly composed of the *stolochœnus, juncus acutus*, juncus *maritimus*, mixed with the roots of *helodes* and myrica gale, furnishing an indifferent peat. Sometimes living pholades (Brongniart says,) may be detected in it. Of course, he adds, it must be covered by the sea at high water. Marine shells are frequently blended in it.

In no other species of moss can these marine productions be found.

It always contains *sea salt*, and frequently a very great proportion of it. When diluted in water, this salt is dissolved, and may easily be detected by the taste. It is of a bitter fetid smell, when turned up.

When *dug and dried* it burns with *difficulty*, and a kind of *hissing sound*. It emits a more *fetid* and *intolerable* smell than any other kind of moss. The smoke of it is not only disagreeable, but often *dangerous*. It always communicates a livid death-like hue to the countenance, and a sickly squeamish feeling, sometimes faintness and a syncope, when burnt in a close room. The flame of it is *blue*. And a whitish yellow efflorescence appears on the pot or iron vessel placed on it while burning.

Picard and many other Dutch authors ascribe all

these distinct characters to the sulphur it contains. Lemnius supposes that they are owing to the bituminous oil in it. To remedy the evil, he observes, that the Dutch often sprinkle sea salt on the peat while burning. But Degner discovered that this, in place of remedying, increases the evil. And he judiciously ascribes these qualities to the sea salt it contains. For the more any peat is impregnated with this, the more fetid, intolerable, and dangerous the smoke of it is. He adds, that salt sprinkled on any peat, produces a similar colour in the flame it yields. And that when common sea salt is distilled with sand, it leaves a similar efflorescence on the retort.

When *reduced to ashes* it still retains some of its distinct characters. Though these be in many respects similar to the ashes of fibrous, compact, bituminous, calcareous, or even pyritous peat, they differ from them all in this *one* respect, that they contain always some, and frequently a considerable quantity of *magnesia soda*, or the *salts* they form.

As in every stage, whether wet, or dry, burning, or reduced to ashes, it possesses distinct features from every other kind of moss, there seems to be no impropriety in giving it an appropriate name, and considering it as constituting a different genus of peat. The propriety of this distinction, will appear in a much clearer point of view, (in the subsequent essays) when it is considered as a soil, manure, fuel, or fit for other economical purposes.

As to the *situation* in which this genus is found, and the extent of surface it covers, the following hints are subjoined. It is obvious, that such mosses can only be expected in *three* situations, that is, along the sea shores, or in such places as have been recovered from the sea, or near rocks of salt. In the *first* of these situations, such mosses have been discovered in the south, east, and west coasts of Britain, in almost every maritime county. In Cornwal, Marsh Mezarion—in Kent, Romney—and in Essex, Renham marshes, are all of this description. In Cumberland, and along the coast of Wales, and Somersetshire, similar marshes have been discovered. In Sussex, in the vicinity of Rye, in Kent near Sandwich, all along the shores of Lincoln, Norfolk, and York, and along the banks of the Thames, below London, salt marshes may be found. The same is the case along the coasts of Scotland, Ireland, and the western isles. Along the whole shores of Holland, Friezland, and the Baltic sea, the mosses are often of the same description. Those of the Somme in France, are similar; at least some strata of them yield *soda*.

Even in more inland situations, salt marshes have been found. Between Bristol and Gloucester, and the whole of Sedgemore, is a salt marsh. The whole valley of the Somme in France has been reclaimed from the deep, and the moss which now occupies the place of the sea, is impregnated with sea salt. Richborrou in Kent was once a sea-port town, though now a mile distant from the coast. Limen and

Romney, though now four miles distant from the sea, and Eye in Suffolk, though now twelve miles distant, were once sea-port towns *.

In all of such marshes, sea salt mixed with marine moss may be expected. Magnesia, soda, and the salts they form, may, therefore, be expected in the ashes of such peat mosses.

Whether any of the mosses of Aberdeenshire are of this description, it is not said. But Dr Skene Keith, in a letter to me, mentions, "that the inhabitants at one period, used the ashes of peat in place of salt." There is no doubt, that the braack torf in Holland, has been, and still is burnt in some places, for the purpose of extracting the sea-salt it contains.

It is almost superfluous to add, that as marine moss covers such an immense surface, thousands of acres in the world may be of this kind. It may, however, be hinted, that the Board of Agriculture in England, the Highland Society of Scotland, and the Irish Agricultural Society, would consult the interests of agriculture, were they to direct their attention to this subject. It is one which comes under their immediate inspection, and consistent with the patriotic ends for which such societies were at first established. An actual survey of the whole coast of Britain and Ire-

* Leland says, that ships came up to the former, within the memory of man. And Dugdale mentions, that, in digging ditches near the latter, rudders, barge nails, and naval instruments, have been discovered. The whole of Marshland, he endeavours to shew, has been recovered from the deep.

land, and of all the mosses these islands contain, promises to be productive of immediate and *lasting* benefit to the Empire at large. To point out the advantages of such a measure, or the plan by which it ought to be conducted, is not the province of the author of these essays. It would be presumptuous in him to make the attempt. He is satisfied with suggesting the hint, that such a measure claims their attention.

SECTION X.

GENERAL CONCLUSIONS.

I. That the appropriate technical name of all moss is geanthrax, or coal of earth. Peat moss corresponds to this. Properly speaking, the name *peat* ought only to be applied to *dried* moss. The single word *moss*, ought to be applied to a *piece* of wet, newly dug peat. M. De Luc, however, observes, that this name is already appropriated to the *musci*. To remedy this defect, it might be written, as in its original Celtic orthography, MOS. If so, there would be no ambiguity in using the term. *Peat moss*, on the contrary, is the appropriate name for a marshy level, in which that substance abounds. And *peat moor* is descriptive of the same substance,

in a drier situation. Moss *earth* is a description of that substance, when partly or wholly converted into a soil.

If this mode of speaking be correct, and if these appropriate names were never used promiscuously, much ambiguity might be avoided.

When moss is considered as capable of being converted into a soil, it would appear that the above classification may be of use; and if the author might be permitted to avail himself of it, and the reader would always keep it in eye, it might save much circumlocution in the subsequent Essays. It would then be known, at once, what genus of peat moss was meant when it was called fibrous or compact, bituminous or peat earth, &c. &c.

It is not insinuated that this classification is correct, or that the description of each genus is complete. There may be varieties of that substance not included in the above arrangement. As far as the author knows, and as far as the interests of agriculture are concerned, it includes every variety of peat moss that can be converted into a soil, manure, fuel, or any other economical purpose.

There are, no doubt, obvious objections to the above arrangement. These may, perhaps, be found sufficient to discard it altogether. It may justly be said, that all these varieties insensibly graduate into each other; so that it is impossible to fix the precise boundaries of any one. To this it may be replied, that the same objection lies against all the at-

tempts that have been made to classify every unorganized substance in nature. It may be farther urged, that a variety of different kinds of moss may be found on the *same spot;* that the surface will be found to be fibrous; the next stratum compact; a third bituminous; a fourth calcareous, and, perhaps, a fifth and sixth pyritous, or marine. This is strictly *true;* but it is no objection to the above classification; for the same is the case with coal, and calcareous matter of all kinds. It may be said, too, that, even on the surface of the *same* moss, and at a small distance, too, different genera of that substance may be discovered. This is literally true. Fibrous and compact moss may be detected sometimes in alternate patches. The former contains vegetable matter in an organized state on the surface, and in all the strata of it, to the very lowest; whereas the latter contains little or none, in any part of it. This is particularly the case with those mosses called, in Ireland, *bog trotters*, and some in Scotland are of the same description. The fibrous peat in these is almost entirely composed of cotton-weed (the eriophorum). It forms such a tough, tenacious, incorruptible substance, that it constitutes a firm organized congeries of vegetable matter; whereas the compact peat, being composed of other plants more liable to decay, is a soft pulpy mass. If the latter were removed, as it may be by rains or floods, the former would appear as so many pillars erected on the spot. This, however, is no reason why these very *different*

substances should not be discriminated by different names. In coal mines, and metallic veins, the case is often similar as in moss. One part of the *same* vein is rich in ore, and another poor; one part of the same seam of coal is blind, and another bituminous; but no one ever urged this as an argument against the classification of coal, or mineral veins.

II. If the above classification be correct, it is clear to demonstration, that these *different* genera must require *different treatment*, either as a soil or manure. No *one soil* can differ more from *another*, in consistency and chemical qualities, than *fibrous* from pyritous, or bituminous from peat earth. And it were equally absurd to cultivate all these different kinds of moss in the *same way* as to apply *one plaster* for all sores. There is no panacea in the art of medicine. And in the cultivation of moss *there is*, there *can be*, no *one general plan* adapted to *every variety* of that substance.

Some of the above genera contain, in *themselves*, the *best materials*, and the best *manures* for their improvement. They stand in no need of *adventitious* aid. Others are so absolutely *sterile*, that the expence of reclaiming them as a soil, would surpass their value. To some, *lime* may be applied with great effect. Others stand in need of no such manure. Some may be pared and burnt to vast advantage. Others would be *utterly*, and for years, if not for *ever*, ruined as a soil by this practice.

In some mosses, *dung* will operate immediately, and long; applied to *others*, it will be of *little* or *no* avail. Some may serve as a soil, a manure, or a fuel. Others are less adapted to any of these purposes; and yet they may be made subservient to *others*, of *equal* or *greater* importance than any one of them. Solutions of alkali, or of dung, will speedily convert *some* into a *manure* or a *soil.* In others, it will not avail.

It is from want of due attention to this, and from the *misapplication* of *manure* and *money*, in cultivating *different* kinds of moss, by *one* and the *same means*, that so many have *failed* of success. Hence the common cry against *every* attempt of this kind. Hence the sarcasms and sneers of the vulgar. And hence, if the application of *lime* succeed in *one* moss, all adopt the *same* mode of culture, as if LIME ALONE could succeed. And if *dung* succeed in another case, lime is *condemned* and dung extolled, as the ONLY *manure* for *every* moss. Such *failures*, and such *misapplication* of *labour*, *money*, and *manure*, has done *essential injury* to the interests of agriculture. Every new *case* of this *kind*, raises and *redoubles* the clamour. And the *richer* the *proprietor*, and the more he *expends* or *throws away* in the experiment the *louder* the *cry*, and the *stronger* the *prejudices* of the public against such attempts becomes *.

* Instances might be easily pointed out, in which much labour and

Whereas, if we would FOLLOW NATURE, and mark *her* slow, silent, and powerful hand, perpetually at work, and lend the *feeble aid* of *art* to her operations, *success* would be *certain* in *every* attempt *.

III. If the above account of the genera of mosses be correct, we may see the cause of the ambiguity and uncertainty that attends the chemical analysis of that substance. When carried on in the destructive way, it is attended with many disadvantages. The expence, the accuracy, and chemical skill it requires, are so seldom at the call of the cultivator, that few

large sums of money have been expended to no good purpose, in such attempts. Whereas, half the labour, and one-tenth of the expence, might have converted such mosses either into a rich soil, or fertile meadow. To specify these instances, might appear invidious. To prevent such misapplication of labour and money, and to point out the way in which these may be expended to better purpose, is one great object of the author in these essays.

* It was *this consideration* that first excited the attention of the author of these essays. It is this still that prompts him to publish them, and pursue the plan with persevering ardour. And it is this that suggested the subjects of *all* these essays on the Natural History of Peat Moss. However foreign they may at *first sight* appear, it will be found that they *all* point to, and terminate in this one conclusion, that, if we *follow nature*, moss of *every kind* may be reclaimed as a *soil*, converted into *manure*, or *fuel*, or some OTHER economical purpose, of equal importance.

The knowledge of the subject is still in its *infancy*. And ages may revolve ere it arrive at maturity. But if the chemist and natural historian would survey peat moss with as much care as they have done the vegetable, the mineral, and the animal kingdoms of nature; there can be no doubt, that much light might be poured in on this intricate, but *interesting* subject.

in the kingdom could carry on such experiments with advantage. This is not all the impediment that lies in the way. If mosses are formed in the manner, and of the materials above-described; if one is chiefly composed of organized, and another of inorganized vegetables; if one contains such a vast proportion of bituminous matter, and another so small; if one is composed partly of calcareous earth, and another contains none; if clay, sand, pyrites, marine salt, enter into the composition of some, while in others none of these substances can be detected; it is as clear as a sun-beam, that the result of chemical analyses must be very *different*, in such different substances. And it is equally clear, that the analysis of *one* genus cannot apply to *another*. Were this all the difficulty, it might be overcome. A correct analysis of *each of these genera*, carried on by a Hatchett or a Davy, might *at once* serve for *each*. But even here, there is an insurmountable obstacle. All bituminous moss does not contain the same *proportion* of bituminous oil; nor all calcareous, or pyritous, or marine moss, the same proportion of lime, iron, or sea salt. An analysis of *each genus*, therefore, would not apply to *all* the varied *gradations* in which it exists. Nay, more, several genera of moss may exist on the surface, or near the surface of the *same field*; and all the varieties of that substance may, in some cases, be detected in the different strata of the *same moss*, and on the same *spot*. It is obvious, therefore, that the result of analysis

would be different, according to the different *parts* of the *moss* that were subjected to it, and the *depth* from which that moss was taken.

How precarious then must it be for any tenant, or even proprietor, to attempt, on these principles, to convert moss into a soil or manure? And how impracticable must it be for any man to analyse every species, and every spot of moss, for these important purposes?

There are, however, other modes of proceeding, much more simple and less expensive; modes, too, which are sufficiently accurate and certain, which require less accuracy and skill, and which may serve all the purposes of the cultivator. A few simple reagents, which may be easily procured, as they are always at hand, is all the apparatus requisite. The application of these to every species of moss, and in every state in which it is found, is easy, and the result is obvious, and almost immediate, whether they be applied to it when wet or dry, burning or reduced to ashes. The method of applying these agents, shall be detailed in the Practical Essays on Peat Moss as a soil, a manure, a fuel, &c *.

* He intended to have published an appendix to this volume, in which the typographical and grammatical errors of the two first Essays would have been corrected. But, as he has procured much valuable information, and many very important strictures on these Essays since they were published, all of which he intends to be noticed, with gratitude, in that appendix, he is under the necessity of withholding it, lest this volume should exceed the ordinary number of pages. He embraces this opportunity of expressing his obligations to the noblemen and gentlemen who have honoured him with the above information.

PRACTICAL ESSAYS

ON

PEAT MOSS,

AS A

SOIL, MANURE, FUEL, &c.

SHORT OUTLINES

OF SOME OF THE

PRACTICAL ESSAYS.

ESSAY I.

On Peat Moss, as a Soil.

SECT. I. On Draining Moss.

1, The depth of the drains,
2, The modes of cutting them by different nations,
3, Width,
4, Advantages and disadvantages of different methods.

SECT. II. On Digging and Ploughing Moss.

1, The season most proper,
2, Manner of digging,
3, Implements fittest,
4, Effects of turning up moss.

SECT. III. On Flooding Moss with running or stagnant Water.

1, What kinds of Moss ought to be flooded,
2, What season of the year, and length of time,
3, Quality of the water,
4, Effects of flooding great and immediate.

SECT. IV. On converting Moss into rich Meadows, by Watering.

1, How this may be done,
2, At small expence.

SECT. V. On making Roads—Railways—Canals through Moss.

1, Different modes adopted in different countries,

2, Advantages of each to different situations,

3, Vast advantages of small canals.

SECT. VI. On Paring and Burning.

1, The best and least expensive mode in some mosses,

2, Absolutely ruinous to others,

3, Advantages and disadvantages attending the practice,

4, Vast success which has attended it,

5, Precautions requisite in every case, and directions,

6, Reasons why it succeeds in some cases, and fails in others,

7, Expence attending practice.

SECT. VII. On Moss Cottars.

1, Vast advantages attending,

2, Method for establishing cottaries in different countries,

3, Modes of building houses for cottars,

4, Terms and duration of leases.

ESSAY II.

On Manuring Moss, as a Soil.

SECT. I. Different Mosses require different Manures.

SECT. II. In what cases Lime ought to be applied, and how it Operates.

1, Mechanically,

2, Chemically,

3, Cases in which it fails,

4, Causes of this,

ESSAY III.

On Moss, as a Manure for other Soils.

Sect. I. Of Moss without any Mixture.

1, What kinds of moss fit,
2, How to prepare it,
3, When and how to apply,
4, To what soils applicable.

Sect. II. Of Peat Ashes.

1. Qualities very different,
2, Some of vast value,
3, Others less,
4, What kinds of peat ought to be burnt for this purpose,
5, How these ashes operate,
6, To what soils applicable.

Sect. III. Moss compounded with Dung.

1, Manner of compounding,
2, State in which the moss ought to be,
3, Kinds of moss fittest for the purpose,
4, Quantity of moss to dung,
5, Soils to which it is applicable,
6, Vast importance of such compost.

Sect. IV. Moss Compounded with Urine from the Dunghill.

1, Cheap mode of preparing,
2, Value of this manure,
3, How it operates.

Sect. V. Moss compounded with Lime.

1, What kinds of moss,
2, How to prepare,
3, When and how to apply.

Sect. VI. Moss compounded with Animal Matter.

1, Whale blubber,

2, Garbage of other fish,
3, Or a solution from these or other substances.

SECT. VII. Moss burnt together with Lime.
1, Lime may be burnt with *wet moss*,
2, How this is done,
3, What kinds of lime, and lime-kilns,
4, A valuable manure.

SECT. VIII. Moss and Clay burnt together.
1, How this is done—form of kilns,
2, This a most valuable manure,
3, Not expensive.

N. B.—The OUTLINES of
ESSAY IV. On Cropping Moss with various kinds of Grain, Grasses, &c.
V. On Moss, as a Fuel,
VI. On Charring Peat,
VII. On the other Economical Uses of Moss,
VIII. Of the Practical Essays, shall be mentioned as soon as the above are Published.

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